AUGUST 1958

THE BEAMA JOURNAL

A QUARTERLY REVIEW OF

BRITISH ELECTRICAL AND ALLIED ENGINEERING

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A QUARTERLY REVIEW OF BRITISH ELECTRICAL AND ALLIED ENGINEERING

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Editorial

The British Electrical Power Convention

To those who attended the British Electrical Conference in Brussels last May, the theme of the British Electrical Power Convention in Brighton in June must have had a somewhat reminiscent ring about it. It was, of course, entirely appropriate that in this year of the Brussels Exhibition, both conferences should be concerned to emphasize the extent and significance of Britain's contribution to the electrical progress of the world.

Space does not permit the publication in our columns of the complete text of the five papers read at Brighton (as we were able to do in our May issue with the two papers read at Brussels); nevertheless, we have included in this issue carefully edited condensations covering the main points of all the papers.

Sir Christopher Hinton's authoritative survey of the development of nuclear energy in Britain showed conclusively how far, and how rapidly, this country has progressed in this field. One basic fact which emerged pretty clearly was the imminent need to increase the country's load factor, and several speakers in the discussion laid stress on the possibilities of pumped storage schemes in this connexion. Sir Christopher said that he was very interested in investigating the possibilities, but he felt that the transmission problems involved were formidable.

He reassured the speakers who had expressed concern about his forecast of the nuclear generation programme by stating categorically his belief that the first stage of the programme and the choice of graphite-moderated gas-cooled reactors were completely right. Our nuclear programme was its own best advertisement abroad. However, we must not refuse to recognize the difficulties, and technologically there was no problem in designing reactors for varying loads; Calder Hall, for example, could vary its load more easily than a conventional station. The question was one of cost rather than technology, since costs were based on maximum generation.

Sir Claude Gibb's paper, informed by his wide personal experience of and contacts with the export markets of the world, was an eminently realistic appraisal of the export possibilities in the nuclear energy field, and although he agreed with one of the discussion speakers that we should be careful not to overdraw the picture, this country was exceptionally well placed to sell experience, knowledge, and training to other countries. Several speakers again referred to the possibilities of nuclear power stations in conjunction with pumped storage schemes to increase the load factor under which the nuclear plant operated—a development which Sir Claude endorsed.

The discussion on Mr Beard's paper ('Britain's Part in Electrical Development Overseas') brought out several important aspects of Britain's efforts in the export field. One —in connexion with the financing of overseas projects— was the difference between finance provided by the World Bank, which has no strings attached to its loans, and the Export-Import Bank of Washington, which attached a condition that its loans had to be spent in the USA. Mr Maxwell Buist (Export Director of BEAMA) emphasized the outstanding importance of foreign languages to engineers engaged in the export field, and the equal importance of training for export. Cooperation between manufacturers was, he maintained, vital to the export business, particularly since UK firms had to tender for every project, while manufacturers in other countries could pick and choose. Exporters had served the country well; they needed and deserved every help and encouragement.

An interesting point in the discussion on the hydro-electric paper was the very useful materials stress testing ground afforded by the operations of the North of Scotland Hydro-Electric Board, and in fact Britain was now as well off as any country in the world for testing facilities. Since American authorities will not accept unproved equipment, the tests carried out for industry by the NSHEB have been of great value in helping us to secure some of the large American orders, and this collaboration between manufacturers and the supply industry was freely acknowledged by the authors of the paper.

Supporting the authors' remarks about the life and economy of hydro-electric stations, it was mentioned that the pre-war Scottish hydro-electric stations were still producing electricity at about one-third of the cost of a station using conventional fuel.

Many comments were naturally made about the new

Blaenau Ffestiniog pumped storage scheme, and it was pointed out that this was a pioneer scheme which would afford, among other things, valuable data for the exploration of the economics of pumped storage schemes.

Points of interest in the discussion on Mr Bernard's paper were that building societies should be more far-seeing and elastic about including the cost of essential electrical equipment in their mortgage advances; that the rôle of the home economist in industry was of increasing importance, both to the manufacturer and the appliance-using public; and a note of surprise by one speaker that no mention had been made of the possibilities and advantages of heat pumps for domestic application.

To sum up, this tenth British Electrical Power Convention must surely go on record as one of the most successful of the series, and the complete Convention Proceedings when they are published will greatly enhance Britain's prestige in the electrical field.

Atoms for Export

Britain's contribution to the 2nd United Nations 'Atoms for Peace' Conference and Exhibition at Geneva next month will be entirely commensurate with this country's leading position in the field of nuclear engineering and exports. The British section of the exhibition, for example, will be by a large margin the biggest national display; the papers to be read by British scientists and engineers will form an appreciable proportion of the whole proceedings. Even more important is the fact that the British story is firmly based, not on hopes and expectations, but on solid achievements and practical experience. For example:

It was emphasized by more than one speaker at the British Electrical Power Convention that the reliability, safety, and economy of the British type of reactor—the gas-cooled graphite-moderated Calder type—have already been proved in more than two years of service.

To quote Sir Claude Gibb in his Convention paper: 'Only a nation which is actually operating nuclear stations can provide the training and experience so essential to satisfactory or indeed safe performance. Britain is in that fortunate position.'

This country is the largest exporter in the world of radioactive isotopes.

Britain has sold the first nuclear power station to be built in Europe for normal electricity generation—the 200 MW station in Italy, for which the agreements have now been or will shortly be signed.

The first nuclear power station to be imported into Japan will be of the Calder Hall type, and British tenders have been invited with a view to starting construction at the beginning of next year.

These few out of many other evidences of the enterprise and achievements of British industry can be compared with the recently concluded agreement between the USA and 'Euratom' (the European Atomic Energy Community), which provides for the installation of about 1000 MW of generating capacity by 1963, nearly half the cost of which may be covered by long-term credits by the US Government to Euratom, and a 10-year joint research and development programme.

In effect, the agreement provides financial assistance from US Government funds for commercial sales abroad, and enables America to use the European countries concerned as a proving ground for the types of reactor favoured in the USA—probably boiling water or pressurized water reactors using enriched uranium.

But there is a wide margin between the 1000 MW programme foreshadowed in this agreement and the original Euratom objective of 15,000 MW by 1970 (even if this should be somewhat retarded or reduced), and it can be taken for granted that British nuclear engineering firms will exploit these opportunities to the utmost—both at Geneva and elsewhere. It is, however, very necessary that the requisite agreements between this country, the European Atomic Energy Community, and its appropriate member governments should be concluded at an early date, and it is to be hoped that the discussions now under way will make this possible.

The British Days at Brussels

The British Electrical and Allied Industry's Exhibit at the Brussels World Exhibition grows steadily in popularity and prestige as the daily total of visitors mounts. Already over 2 million people have seen and acclaimed the British Pavilions, among them a steady stream of technical visitors who are attracted and impressed by our Industry's exhibit and whose inquiries about many different kinds of equipment are regularly passed on to all supporting firms and associations.

In the series of 'National Days' held during the Exhibition, the British Days were celebrated on July 10, 11, and 12, when the focal point was the visit of HRH the Duke of Edinburgh, who spent over an hour of his crowded time-table in visiting all the stands in the British Industry Pavilion and stayed for about ten minutes at the British Electrical and Allied Industry's Exhibit. He was conducted round the stand by Mr J. O. Knowles (Chairman of the BEAMA Council) and Mr D. Maxwell Buist (Chairman of the Organizing Committee), and examined all the exhibits with keen and critical interest. Indeed, he diverged from the planned route through the stand to study in detail each of the six overseas features.

The Duke's party was followed by another distinguished group led by SAR Le Prince de Liège and high-ranking Belgian personalities, and other parties included many well-known personalities from Britain led by Mr F. J. Erroll, Parliamentary Secretary, Board of Trade.

Among other interested visitors to the British Electrical and Allied Industry's Exhibit on recent occasions were Their Majesties the King and Queen of Nepal, and distinguished personalities from a large number of countries overseas. It is hoped to welcome many more visitors to the British Industry Pavilion and the Electrical and Allied Industry's Exhibit before Brussels closes on 19 October, whether their interest is general or specifically technical.

Cover illustration. *During his tour of the British Electrical and Allied Industry's exhibit at the Brussels Exhibition, HRH The Duke of Edinburgh had many comments to make on the exhibits. The camera has caught him just as he turned to make a remark to Mr J. O. Knowles (on the right) about the Lisbon-Oporto Telephone System. On the Duke's immediate left is Mr D. Maxwell Buist.*

Battery Emergency Lighting Plant

A. Prescott, AMIEE*

ELECTRICITY supply failure, black-out, and other hazards would present serious problems if it were not possible to provide an economical and reliable standby lighting equipment. The standby plant installed should be instantaneous in action and sufficient to minimize the risks associated with power failure. The most popular type of equipment includes a lead acid or steel alkaline stationary battery and the necessary control gear. The importance of the storage battery in modern electrification schemes is clearly shown by the diverse applications for which standby batteries are installed, because, despite the utmost precautions, failures of the normal ac supply do sometimes occur.

One of the many important modern applications of batteries is that of providing a source of standby power, *i.e.* an insurance against the possibility of failure of the normal ac supply. Weather conditions, overloading, and cable faults are some of the reasons why failures do occur and it is a tribute to the electrical supply industry that the failures are so infrequent and that the majority are generally for short periods only.

The recognition, therefore, of the risk that the normal ac supply service might fail without any warning, and of the possible consequences, has resulted in consulting engineers, architects, factory executives and responsible bodies giving serious consideration to the provision of standby equipment. Such consideration should preferably be given when new buildings or development projects are conceived, and not left as an afterthought or be dependent upon the amount of money 'left over'.

Undoubtedly the major consideration must be to provide an adequate source of emergency lighting, since light is of such importance that it is difficult to envisage modern life without the illumination provided by artificial electric lighting.

Adequate illumination at all times is necessary for the maintenance of morale where crowds congregate, whether for work, sport, or recreation. The growing popularity of floodlit games, particularly football, is one of the latest applications for which batteries have been installed to provide emergency lighting. The hazard created by the loss of illumination in factories using rotating, chemical, or boiler plant may result in serious accidents and compensation payments well in excess of the initial cost of providing emergency plant.

Lighting in hospitals may prove to be a matter of life or death in the operating theatre, and sufficient illumination ought to be provided to enable the hospital to function satisfactorily at all times. Humanitarian considerations, such as those found in hospitals, should not be jeopardized by the availability of resources, since this results in the minimum rather than the essential amount of emergency plant being installed.

In departmental stores, hotels, places of amusement, public buildings, and any place where failure of normal lighting would create a hazard, it is now the accepted practice to install emergency lighting plant. Even modern power stations, both nuclear and orthodox steam stations, as well as substations, require adequate lighting at all times, and it is usual to provide storage batteries and emergency control gear for this purpose.

So far as legal requirements are concerned in Britain, one type of building—the cinema—must have emergency lighting to the requirements of the regulations issued by the Home Office. Theatres are also required to have emergency lighting, as well as other buildings having music and dancing licences. Local authorities are also able to insist on the provision of emergency lighting in a variety of premises where people may assemble.

Thus, as modern development proceeds, we become more dependent upon electrical power and reliable standby equipment, whether installed for morale, humanitarian, or legal considerations.

To understand the popularity of batteries for standby applications it is necessary to set out the essential features of a standby source and to examine what alternative standby sources are available.

Essential Features

The essentials are reliability; the ability to give instant emergency power; to remain idle for several months and then spring into action immediately upon supply failure. These features, together with a minimum of maintenance, explain the popularity of the storage battery and why it is generally considered to be a sound investment. Quiet operation of the equipment may also be important in certain installations, such as hospitals or broadcasting studios.

Standby sources other than batteries may be provided by candles, oil or gas, or engine generator sets. The first three need not be considered since the tendency is to replace these sources by modern electrical installations when old buildings are renovated. The two sources generally considered are, therefore, either batteries or engine generator sets. Each of these alternative sources has its particular sphere of application. The battery-fed emergency lighting plant is eminently suited for most standby periods from 30 minutes to 3 hours, while engine sets are included if there is a likelihood of a prolonged standby period being required, *i.e.* 24 hours or more. The fact that the majority of supply failures are of relatively short duration, *i.e.* less than 3 hours, therefore favours the use of battery-fed emergency lighting.

In certain larger installations a compromise is made by including a battery to cater for the first 30 minutes of any failure and also to start up automatically an engine generator. The battery, under these circumstances, will perform two extremely important functions by (*a*) giving instant emergency power, (*b*) ensuring that the automatic engine set has time to run up to speed. Failure of the set to run up to speed automatically will mean that there is a period of 30 minutes to decide upon any necessary action, with the knowledge that this 30-minute period is adequately provided for.

* Chloride Batteries Ltd.

The suddenness and absence of warning of a failure might provoke panic and there should be no delay in providing emergency power. The manual starting of an engine generator set (where this is appropriate to the circumstances) means that there is a lag between the time of failure and provision of a standby supply, and this may not be acceptable. It is therefore good practice to have fully automatic engine sets and to duplicate these so that one acts as standby to the other.

One type of engine generator set will give instant emergency power if normal supply fails, but the higher cost of this set for the popular ratings and applications has meant that it has not so far been seriously considered. It is not the intention here to discuss the pros and cons of batteries against engine generator sets, but to make appropriate references to alternative methods so as to indicate the sphere of battery applications.

The two main components of battery-fed emergency lighting equipment are:

(*a*) The storage battery.
(*b*) The control gear.

The battery may be considered under two main types, *i.e.*

(i) Lead acid storage batteries.
(ii) Steel alkaline batteries.

Lead Acid Batteries

The majority of installations use lead acid batteries, and over twenty-five years' experience has proved that the Planté positive plate type of lead acid cell is pre-eminent in meeting the requirements of a standby battery. Many lead acid battery installations in Britain have been in service for this period of time and are still working with the original plates and electrolyte.

The Planté positive plates are made of pure lead and are developed by means of lamelles to give a large surface area. An electro-chemical formation process is used to produce a thin layer of lead peroxide on the surface of the lamelles, leaving the remaining pure lead unchanged in the body of the plate. The negative plates contain active material in a box of perforated lead sheet having an antimonial lead frame.

The positive and negative plates are separated by dowels combined with diaphragms of wood or plastic. The addition of a diaphragm covering the whole of the plate area is a safeguard to prevent internal short-circuit.

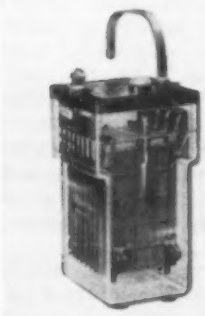

Fig 1. Typical sealed type lead acid cell

The electrolyte is dilute sulphuric acid having a specific gravity of approximately 1·210. The gravity varies throughout a charge/discharge cycle.

The lead acid cell having the plates assembled in a glass box, as shown in Fig 1, is the type most commonly used for the applications of emergency lighting. This type of cell is referred to as a stationary sealed cell.

Sealed cells can be supplied from the manufacturer's works and sent to site filled with acid and fully charged. They are easier to erect and easier to maintain. They are also suitable for dusty atmospheres. The choice is usually in favour of the sealed-in lead acid cell, unless the capacity required is in excess of the maximum capacity available in the manufacturer's range. To utilize the advantage of the sealed cells it is fairly common practice to parallel sealed cells and thus increase the capacity available. Because of the absence of electrolyte spray, sealed cells may be housed adjacent to the control gear, thus minimizing the space required for gear and battery. Fig 2 shows a typical installation. Sealed cells are available with capacities of from 10 Ah to 450 Ah at the 10-hour discharge rate.

The alternative lead acid stationary cell—the open type—is normally supplied unassembled with the acid in a separate container. Assembly takes place on site. Open types of stationary cells may be assembled in open glass boxes, or for larger capacities in wood lead-lined boxes.

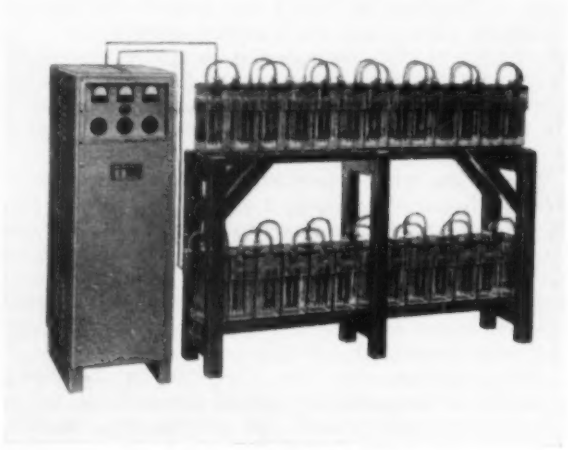

Fig 2. Typical sealed cell installation

Steel Alkaline Batteries

There are two designs of steel alkaline battery available —the nickel-cadmium type and the nickel-iron type. Nickel-cadmium types are normally used for emergency lighting, stationary and general standby duties, because these cells will hold their charge better on open circuit. A fully charged nickel-cadmium battery will retain 80 per cent of its capacity over many months on open circuit. Unlike the nickel-cadmium types, nickel-iron cells lose their charge quickly if left on open circuit, and since these cells will not absorb low rate trickle charge current it is usual to find nickel-iron cells only on duties which involve frequent cycles of charge and discharge, and rarely on emergency work. The nickel-cadmium cells preferred for standby duties have plates which comprise perforated steel pockets for housing the active material assembled into a steel retaining frame. The active material of the positive plate is nickel hydroxide, while that of the negative plate is a mixture of cadmium and iron. The plates are assembled into steel containers suitably plated on the outside to prevent corrosion. The electrolyte consists essentially of a solution of potassium hydrate in distilled water having a specific gravity of approximately 1·200, which remains fairly constant during charge and discharge, and does not affect iron or steel, so that there is no need to treat against internal corrosion. It may be necessary to renew the electrolyte of steel alkaline cells

during the life of the battery, depending upon the service conditions.

Distilled water is used for topping-up steel alkaline cells, but of course on no account must acid be used since permanent damage may be caused.

An important point to note is that the steel containers normally used for alkaline cells are electrically alive because of the conductance of the electrolyte. Nickel-cadmium cells have positive plates in direct metallic contact between the steel cases of the cells.

The individual cell cases are prevented from making metallic contact with each other by mounting them in wood crates, and they are suitably suspended from the side of the crate with adequate air clearance space between to allow normal operation without the risk of a short-circuit.

Smaller sizes of nickel-cadmium alkaline cells may be housed within steel battery cabinets. The arrangement would comprise a number of cells per wood crate and several crates seated on the steel cabinet shelves, depending upon the battery voltage. For larger installations it is usual to house the hardwood crates side by side upon wood stands, somewhat similar to the mounting of lead acid cells.

Discharge Rate

It is usual for a manufacturer to express the capacity of cells, both lead acid and alkaline, at the 10-hour rate of discharge. This is expressed as 100 Ah/10 to a minimum final voltage of 1·85 V per cell for a lead acid cell, or 100 Ah/10 to a minimum voltage of 1·10 V per cell for a steel alkaline cell. This means that the particular 100 Ah cell would give a discharge of 10 A for a period of 10 hours to the minimum voltage per cell stated.

Rating of cells at the 10-hour discharge rate is not directly applicable to standby applications since the discharge periods more frequently considered are 1 and 3 hours. It is necessary, therefore, to be able to convert readily from the 10-hour capacity to the 3-hour or 1-hour capacity for these applications.

Table A expresses the percentage of available capacity for lead acid cells, and shows that a lead acid cell having a quoted capacity of 100 Ah/10 would produce a capacity of 50 Ah for a 1-hour rate of discharge, *i.e.* it will supply 50 A for 1 hour. Also from Table A it will be noted that this same cell has a capacity of 71·7 Ah at the 3-hour discharge rate, which means it will supply approximately 24 A for a period of 3 hours. It is, therefore, important when expressing the capacity of a cell to qualify the rate of discharge. The quoted capacities are based upon a nominal temperature of 60 deg F (15·6 deg C); the capacity of a battery increases slightly with rise in temperature and decreases with fall in temperature.

Trickle Charge Operation

The recommended mode of operation during normal periods when the battery is idle is termed 'trickle charge operation'. Trickle charging replaces the open circuit losses by passing approximately 1 mA per ampere-hour capacity continuously through the cell and involves no wear upon battery plates. The rate of 'trickle' is somewhat less for larger capacity batteries, being 100 mA for a 100 Ah/10 cell, 140 mA for a 240 Ah/10 cell and approximately 210 mA for a 450 Ah/10 cell. Proper trickle charging will maintain the cells in a healthy and fully charged condition indefinitely. There is no need whatever for cycles of discharge/recharge if the Planté plate stationary battery is maintained on trickle charge operation, as recommended by the battery manufacturer.

The precise value of trickle charge to maintain a battery in a healthy condition is usually determined under actual site conditions, since factors such as site temperature may influence the open circuit losses. The correct value of trickle charge current is the minimum which will keep the battery fully charged with the specific gravity of the acid at its maximum. The terminal voltage of a correctly trickle charged lead acid cell is usually between 2·25 and 2·3 V per cell.

Trickle charged batteries will operate for long periods unattended under normal circumstances, but at installations where extremely high temperatures are encountered a periodic check at monthly intervals is recommended. This check would be for the purpose of topping up with distilled water to compensate for evaporation losses.

Cell Voltage Characteristics

Cells have inherent voltage characteristics which vary throughout a cycle of charge and discharge, as shown in Table B.

Table A: Capacity in Ampere-Hours

(expressed as a percentage of the ampere-hours available at the 10-hour rate)

When Discharging in									
1 hour	2 hours	3 hours	4 hours	5 hours	6 hours	7 hours	8 hours	9 hours	10 hours
50%	63·3%	71·7%	78·2%	83·3%	87·9%	91·7%	95%	97·9%	100%

Table B: Typical Lead Acid Voltages at 60 deg F (15·6 deg C)

Rate of discharge	Normal trickle voltage per cell	Discharge voltage per cell		Maximum recharge voltage per cell
		Initial	Final	
1 hour	2·25	1·97	1·75	2·75
3 hours	,,	2·02	1·80	,,
5 hours	,,	2·04	1·82	,,
10 hours	,,	2·05	1·85	,,

This table shows the typical cell voltages that are obtained throughout a normal operating cycle for a trickle charged standby lead acid battery, *i.e.* trickle charge voltage—discharge voltage—quick charge voltage —and reverting to trickle charge for various standby periods. The open circuit voltage of a lead acid stationary cell is approximately 2·08 V per cell.

Control Gear

Control equipment should

(i) be reliable and respond instantaneously to supply failure;
(ii) have a life comparable with the battery, which may be in excess of twenty years;
(iii) provide adequate and simple means for keeping the cells healthy by trickle or quick charge;
(iv) afford easy maintenance;
(v) include components that have been thoroughly tested under operating conditions.
(vi) Any automatic switch must be carefully designed, since the whole equipment is dependent upon it. The principle of switch design must be the automatic transfer of the battery to the emergency lights when a mains supply failure occurs. Automatic switches should not require electrical energy to take them to the emergency position but should operate by springs or gravity or a combination of both to transfer the switch from 'mains alive' to 'mains failed' position.
(vii) The equipment must be correctly selected for the duty.

Equipment Type Selection

The correct type of emergency lighting equipment may be selected by considering the function of the standby plant under normal and emergency conditions. There are three distinct types of equipment available which provide an automatic supply from battery on failure of the mains. These are:

(i) Floating battery equipment.
(ii) Non-maintained, with automatic switch.
(iii) Maintained, with automatic switch.

The 'true' floating battery equipment for emergency lighting applications does not normally utilize the advantage of trickle charging. (Reference to 'true' float should not be confused with floating trickle charge.) It is necessary to have 'true' float because of the voltage regulation permissible at the emergency lights circuit. For example, a nominal 100 V lead acid floating battery would comprise 48 cells floating at 2·08 V per cell to give a normal dc voltage of 100 V to the load. The cells cannot float at less than 2·08 V per cell, since this is the open circuit voltage, and any voltage less than 2·08 would mean that the battery would discharge. Upon supply failure the battery would supply the load for 3 hours to a minimum voltage of 1·80 V per cell, or 86·4 V across 48 cells. If it be desired to utilize the advantage of trickle charge, the number of cells would have to be $\frac{100}{2{\cdot}25}$ (since 2·25 is trickle voltage—see Table B). This results in 44 cells which would mean a final overall voltage at end of a 3-hour emergency of 79 V, which is considered too low for a nominal 100 V system. From Fig 3 it will be noted that a rectifier of the selenium metal or mercury arc type, or a motor generator set, is connected to the ac mains supply and the battery is connected straight across the dc output terminals which also supply the load. The dc output voltage from rectifier or motor generator set is adjusted so that the battery neither charges nor discharges. The rectifier or motor generator set supplies the load when normal ac supplies are available. The advantage of this equipment is that there is no automatic switch which has to operate to put the load circuit across the battery when the supply fails.

There are some disadvantages:

The rectifier or motor generator set must be fully rated to supply the normal system lighting load.

Fluctuations in the load or in the ac mains will necessitate manual or automatic adjustment of dc voltage output to preserve floating conditions. Selenium or mercury arc rectifiers are available to maintain the level of float voltage automatically without frequent attention, and while these are expensive, rectifiers of this type must be used if there is any likelihood of frequent load fluctuations.

Battery life is reduced, because frequent freshening and equalizing charges have to be given to restore it to full capacity since there is no trickle current to compensate for losses.

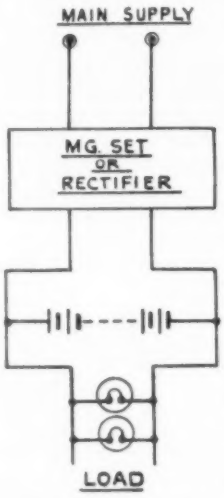

Fig 3. Simple floating battery circuit

The charging of the battery must take place with the load circuit disconnected, otherwise the top of charge voltages quoted in Table B would be applied to the load. It is, therefore, necessary with a floating system to ensure that time is available to carry out a recharge, during which the standby battery must not be required. Extra maintenance and attention is therefore necessary on floating battery equipments.

An equipment is now available which is specially suitable for village halls, school assembly halls, community centres, etc., which require an emergency supply of low wattage for a short period, perhaps once or twice a week.

The equipment for this application would be generally as shown in Fig 4. It is a 12 or 24 V self-contained equipment which operates on the floating principle during the brief periods when the standby is required, but during the greater portion of the time, the battery is switched from the emergency lights circuit to trickle charge operation. The equipment shown will supply 240 W for a period of 3 hours and incorporates a 40 Ah/10 lead acid battery.

This type of equipment is economical and does not contain an expensive automatic changeover switch, but it also has the advantage of trickle charge operation. It is only suitable, however, for installations that require the emergency standby infrequently, since to be effective trickle charging must be in operation almost continuously. It suffers from the same disadvantage as the floating battery in that, during recharge periods, it would not be possible to connect the standby equipment to the lights,

since the high voltage would bring about failure of the lamps.

The floating battery system has been used for many years in cinemas and theatres in certain areas where the local licensing authority would not permit the use of automatic change-over switches. With the development of automatic switches to a rigid and detailed specification, it is expected that the majority of equipments installed in the future will be of one or other of the automatic types.

Automatic Non-maintained Equipments

Figs 5 and 6 show the basic circuits. 'Non-maintained' means that the emergency lighting is not normally illuminated until there is a failure of the mains supply, and the circuit is therefore 'dead' until a failure occurs. The battery is idle and (in the case of lead acid cells) receives a continuous trickle charge from the equipment.

The non-maintained system necessitates a separate circuit of emergency lamps, in addition to the circuit providing illumination from the normal ac supply. The automatic switch may be of the single- or double-pole type, with the coil energized from the mains supply and arranged so that on a mains failure the switch closes the battery on to the non-maintained emergency lights circuit. The battery then discharges according to the discharge rate previously determined. On restoration of the mains supply, the switch will automatically break the circuit between battery and load, and the non-maintained circuit will again become 'dead'.

Only after any appreciable discharge does the battery require a quick charge. A selector switch on the equipment enables a pre-set rate of charge to be given, following which the equipment reverts to trickle charge (or open circuit for alkaline cells). A circuit which is normally 'dead' should not be under the control of any hand switches between load and battery. Failure of the emergency lights to operate when required has been traced several times to isolating switches having been left open, and it is better to have an inadvertent discharge when the lights are not required than to risk the lights not operating at an emergency.

An exception arises when the switch isolating the emergency lights is suitably interlocked with the switch controlling the normal illumination. The switching would then be arranged so that the emergency lights switch would be closed only when the normal ac circuit switch is 'on'.

Automatic Maintained Equipments

With this system the emergency lights are supplied from a circuit that is *always maintained alive*. The circuit is connected to the normal ac supply if the mains are healthy, but the same circuit of lights is automatically transferred to the battery on a mains failure. Thus the lighting is fed from either ac or dc at all required times. (See Fig 7.)

The most common application for a maintained circuit is in cinemas, where legal requirements insist that exit lighting must be illuminated during the whole time the public are on the premises. For ac mains it is usual to select the most economical battery voltage for the maintained circuit and to utilize a step-down transformer to supply the circuit normally. In many cases the voltage of the maintained circuit is less than the supply voltage, *e.g.* 25, 50, or 100 V ac or dc.

The disadvantages of the floating battery equipment mentioned earlier do not apply to the maintained system. Apart from less maintenance, important points in favour of the maintained system are:

(i) The cells are normally operated on trickle charge, and this is conducive to long life.
(ii) The load is normally supplied by the ac mains and does not have to be first converted to dc, as with a floating battery system.
(iii) The number of cells chosen may be increased to any number to satisfy voltage requirements of particular installations. The limiting factor is the need to ensure that for a given number of cells the initial voltage on discharge (given in Table B) does not result in overvoltage and possible failure of lamps immediately the load is transferred to the battery.
(iv) It is possible to charge the battery at the same time as the safety lighting circuit is alive, since supplies for charging and lights are from independent circuits.
(v) The higher charge voltage cannot reach the safety lighting because of the action of the automatic switch.

Charging arrangements for the maintained system are similar to those of the non-maintained system, the principal difference being the automatic switch arrangement and the addition of the step-down transformer (if the chosen battery voltage warrants this feature).

The maintained circuit may be used to form part of the normal illumination in a building and may result in reducing the amount of cable required, which would be

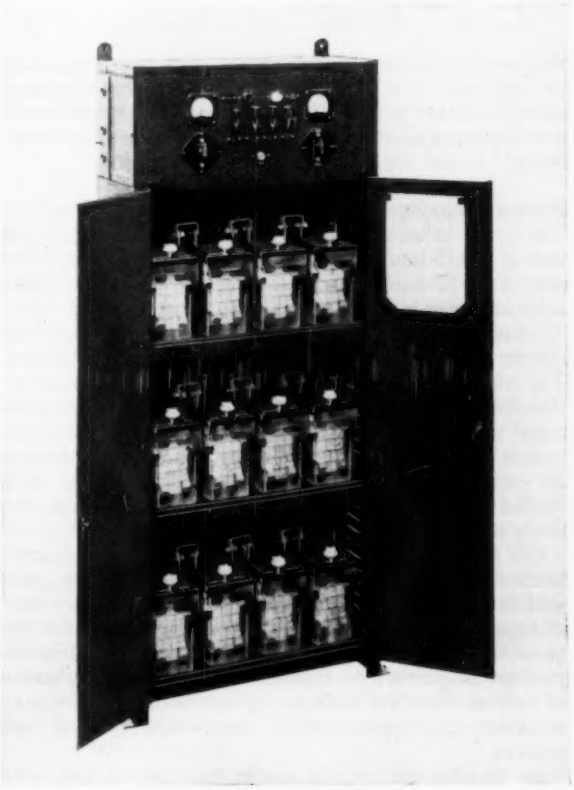

Fig 4. A typical 24 V, 240 W equipment

the case when several selected circuits of lights are connected via a maintained equipment. In the event of mains failure, the same circuits are transferred to the battery. Such selected circuits would often supply lighting points in stairways, corridors, exits, etc., and provide sufficient lighting to prevent any hazard.

It is, of course, wise to ensure that the lighting fittings providing the normal illumination in a building are suitable for ac/dc operation. Many lighting schemes to-day include decorative fluorescent fittings which include starting gear suitable only for ac working. In these circumstances there is no alternative but to run a separate emergency lighting circuit to a number of filament lamps

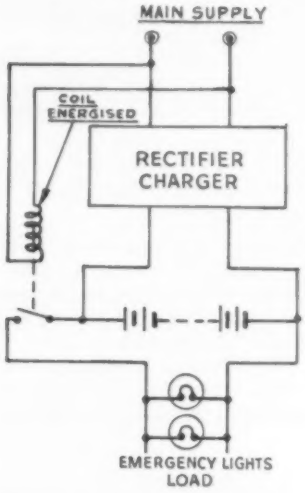

Fig 5. Simple trickle charge automatic switch circuit (non-maintained single-pole scheme)

situated at carefully chosen points. This equipment may be operated as a non-maintained system at the most suitable battery voltage, since the fluorescent lamps would provide normal illumination, and the filament lamps would be 'on' only during an emergency period.

Battery Charging Arrangements

The usual value of current for quick charge is 7 per cent of the 10-hour capacity for lead acid cells, and 10 per cent of the 10-hour capacity for steel alkaline cells. (These rates are known as the 'finishing' rate of charge.)

Since nearly all supply systems are ac, it is necessary to rectify or convert them to dc for charging the battery. The means most commonly used for this purpose for standby battery voltages of 25, 50, and 100 is the selenium metal rectifier. For 240 V battery schemes there is justification on grounds of economy for the use of a mercury arc equipment. Both equipments are static and have tended to supersede the motor generator set for battery charging.

On the important issue of reliability, the glass bulb mercury arc rectifier has proved to have a life comparable with that of the battery and will thus give very many years of trouble-free service. In low temperatures the mercury glass bulb rectifier should be fitted with cubicle heaters, preferably operated by thermostatic control. Adjustment of voltage from the mercury arc rectifier required during a battery recharge is quite simply achieved by grid control.

A standby battery is recharged infrequently and the question of efficiency of conversion is not so important.

The characteristics of selenium metal rectifiers are somewhat complex, and to obtain the maximum reliability and reasonable life the detailed service conditions require to be known by the control gear or rectifier manufacturer. Full-wave rectification is available by means of bridge connexion. Proper cooling is essential for the operation of these rectifiers and full use is made of natural air convection. Selenium rectifier equipments may be mounted within a totally enclosed cubicle, but it is essential that the temperature rise at the rectifier discs is within the manufacturer's upper limit. The mass of the cubicle must be sufficient to ensure adequate cooling.

Variation of voltage on selenium rectifier equipments may be achieved by the use of a rotary selector switch which is connected to the transformer secondary tappings. A fixed choke or ballast resistance may also be used to obtain a suitable taper characteristic of charge current, and this has the advantage that manual attention throughout a recharge is not necessary.

The recharge current should be available throughout a voltage range of 2·0 to 2·75 V per cell for emergency lighting applications.

Trickle and quick charge may be obtained from the same rectifier in the smaller sets, but if the quick charge is in the order of 3 kW, a separate selenium rectifier circuit may be included to provide the few milliamperes necessary for trickle charge.

Where use is made of the mercury arc rectifier for quick charge it is accepted practice to use a small selenium metal rectifier for trickle charge.

Period of Standby

To decide the most suitable scheme it is important to know whether the installation will be subject to approval by the local licensing authority, and any special requirements of the particular authority. In Britain, buildings coming under the licensing authority, such as cinemas, theatres, assembly halls, etc, must provide a battery sufficient to supply adequate standby lighting for 3 hours.

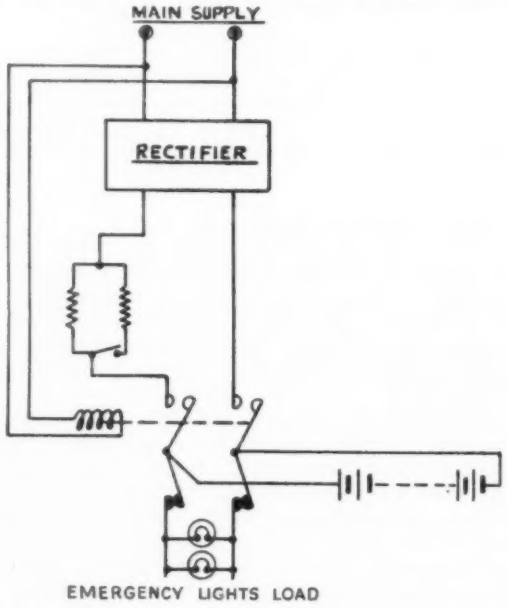

Fig 6. Simple non-maintained trickle charge automatic switch circuit (double-pole scheme)

For hospitals there is no compulsory period of standby, and periods vary from 1 to 3 hours. Other buildings and installations have a battery capacity to fit in with envisaged emergency conditions and the period of standby usually varies between 1 and 3 hours.

Size of Battery

The voltage, discharge current, and period of standby are required to estimate the capacity of battery required. The number of cells may be decided after selecting the nominal voltage, and reference to Table B will enable the minimum emergency voltage to be calculated for a given discharge rate, *i.e.* standby period. The voltage of the emergency battery depends upon the disposition of the lighting circuits relating to the battery, and estimates should take into account the cost of the control gear plus the cost of cables for the emergency circuits. It is more economical from the battery point of view to increase cell ampere-hour capacity and use a lower voltage for a given wattage discharge, though, of course, the lower voltage means increased cable sizes to minimize voltage drop. Between the battery and the furthest lighting point voltage-drop can be appreciable.

The choice of voltage may not always depend upon pure economics since consideration must be given to any special voltage requirements of the lighting system. For instance, various types of main lamps in hospital operating theatres use a number of 24 V high efficiency lamps in a fitting that has no separate circuit of emergency lamps for connecting to a non-maintained system. With this type of lighting fitting the 24 V supply to the lamps must be maintained, from either ac or dc, via a maintained equipment, all the time the operating theatre is in use.

The architectural features of the building or installation will decide the disposition of lighting points, and the emergency lighting wattage needs to be only a fraction of the normal lighting. Small wattage 12 and 24 V lamps are widely used, since the lumen output from low voltage lamps is better than that from the higher voltage mains lamps. A direct comparison shows the initial lumens from a 24 V, 40 W lamp to be at least 500, while a 230 V, 40 W lamp is quoted by one lamp manufacturer as 415 lumens.

Having selected the appropriate battery voltage and decided upon the total wattage of emergency lighting points, the discharge current in amperes is easily calculated. Knowledge of the period of standby (*i.e.* discharge rate of battery) and the discharge current will determine the selection of a suitable battery capacity. Compensation for voltage-drop between battery and load is customarily provided by the use of a few extra cells. Typical numbers of lead acid cells for various voltages on maintained and non-maintained systems are 7 cells for 12 V, 14 cells for 25 V, 26 cells for 50 V, 50 cells for 100 V, and 120 cells for 240 V.

Battery Accommodation

Sufficient room, and of course adequate light, should be available around the cells to inspect the electrolyte. The temperature of the battery room should be kept moderate and preferably should have ventilation direct to outside air. The use of a fan for forced ventilation is seldom required. When cells are on quick charge, four air changes per hour are generally ample for dispersing the gases given off from the cells. For overseas, and particularly in tropical climates, it must be remembered that cell temperatures rise during a quick charge. The upper limit of temperature for lead acid cells of the type discussed is normally about 110 deg F (43 deg C), but for very short periods cell temperatures as high as 125 deg F (52 deg C) are the recommended maximum. Prolonged overheating will shorten battery life.

For steel alkaline cells the normal limit is 120 deg F (49 deg C), but in tropical countries temperatures up to 136 deg F (58 deg C) are acceptable for short durations.

Steel cabinets for housing the cells should incorporate louvres for ventilation and adequate room for the topping up of cells. During the infrequent periods of quick charge, the cabinet doors should be opened.

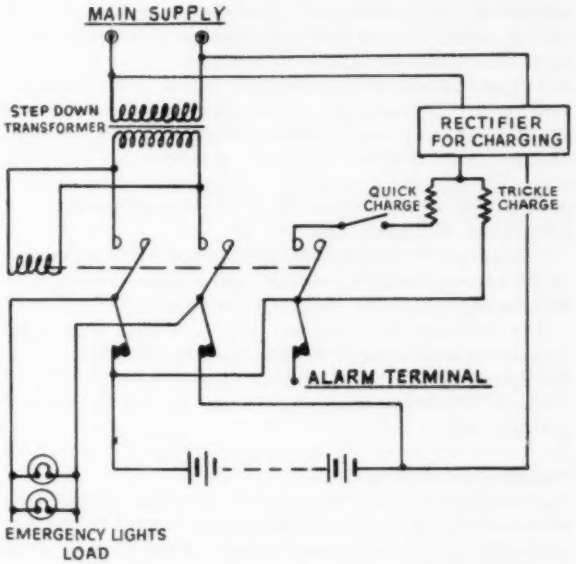

Fig 7. Simplified maintained trickle charge automatic switch circuit

Choice of System

Either a floating battery system or maintained automatic switch system may be preferred by a particular local authority when it is necessary to illuminate lighting points continuously during periods of possible hazard. The many advantages of the maintained automatic switch system should be considered when selecting a system. Apart from legal requirements, certain installations, such as multi-story office blocks, departmental stores, factories, etc, may require particularly long runs of cable to the furthest lighting point, and a degree of illumination may be necessary even during daytime in offices, corridors, stairways, etc. A maintained system would be used and made to form part of the normal illumination. The long runs of cable are thus better utilized by serving both for normal and emergency conditions, as distinct from the non-maintained circuit that is 'dead' until an emergency arises. If long runs of cable are of necessity involved, it is usual for this latter type of maintained equipment to employ a 240 V battery.

The use of a 240 V battery also means that it may not be necessary to provide a step-down transformer for the maintained circuit, since 240 V single phase ac would

normally be supplied to the load via the automatic switch, and during a mains failure the contactor would transfer the load to the 240 V battery.

One interesting application for battery-fed emergency lighting on the maintained system is the provision of pilot lighting around factories to enable a watchman or fireman to carry out his nightly inspection even during emergency periods when the normal mains supply has failed. By suitable switching arrangements, the maintained system can be changed to a non-maintained system during the daytime and so provide a source of emergency lighting for the factory during normal operating hours.

Sometimes a compromise is achieved by having a certain amount of lighting on a maintained system, and additional non-maintained lighting connected to the battery when the contactor changes to emergency position. This would be typical of a theatre load in which the exit signs must be on a maintained system, and additional auditorium lighting on a non-maintained circuit is switched on only during mains failure. In such cases the change-over contactor would be arranged for the dual rôle. The discharge currents of maintained and non-maintained circuits must be added together for the calculation of battery capacity.

Other standby installations not coming within the scope of the above would fall into the general category of non-maintained automatic switching systems.

The maintained or floating system is thus used if we require the same lamp to be illuminated normally and also during emergency, whilst the non-maintained system illuminates a special emergency lamp during emergency periods only.

Hospital Installations

Special mention may be made of emergency lighting in hospitals. The emergency lighting is arranged to provide a standby supply to the total number of main lamps in the operating theatres and to provide a standby supply to corridors, anaesthetic and sterilizing rooms and any other rooms in which essential duties are carried out. The precise emergency system for the main lamps depends upon their type and manufacture. Several different designs are available and some do not incorporate separate lamps for connexion to a non-maintained system. If emergency lamps are included in the fitting in addition to the main lamp, then it is usual to supply the separate lamps from a non-maintained system at the economical battery voltage. Since the emergency lights *must* come on should the main lamp go off, whether because of mains failure, local fuse failure, or lamp filament failure, a special switching relay has been developed for connecting in series with the main lamp. The switching is effected by mercury tubes and the relay can thus be classified as sparkless—a very necessary feature in operating theatres. If separate lamps are not provided, the main lamp is usually supplied from a maintained ac/dc system.

Cinema Regulations

The specialized field of the British Cinematograph Act of 1952 (which revises the 1909 Act) may be reviewed more fully by reference to the following:

1. The Cinematograph Act, 1952.
2. The Cinematograph Regulation 1955: Statutory Instrument No 1129.
3. The Cinematograph Regulation 1955: Statutory Instrument No 1125 (applicable to Scotland).
4. Home Office Circular No 150/1933.
5. Recommendation of Safety in Cinemas.
6. Code of Practice CP 1007 1955.
7. British Standard No 764/1954 relating to design of change-over contactors.

Automatic Switch Design

To meet the demand for a reliable automatic change-over contactor, BS 764: 1954 was introduced. This relates to standard ratings of 15 A, 30 V and 15, 30, 60, and 100 A at voltages not exceeding 250. It applies principally to maintained systems.

Typical Installations

Standard equipments are available from reliable battery manufacturers ranging in output from 120 W to 9 kW at various battery voltages for maintained or non-maintained systems. A number of 240 V maintained system equipments, with output ratings between 10 kW and 20 kW, have been supplied to floodlit football installations for the purpose of maintaining the lighting in dressing-rooms, stands, passageways, and other vital points while the public are on the premises.

A maintained installation is normally supplied from ac mains, and if the required load exceeds 10 kW it is often preferred to balance the ac loading across a 3 phase, 4 wire system. Three separate emergency circuits are then utilized, each with its own 'phase' contactor. A failure of only one phase would mean 1/3 of the total discharge on the battery, while a total failure would put all three emergency circuits across the 'common' battery.

For certain non-maintained systems it is sometimes desired to ensure the illumination of the emergency lamps on a failure of any one phase of a normal 3 phase, 4 wire ac system. This is achieved by using a reliable phase failure relay, which operates the automatic switch and connects the emergency lights to the battery.

Conclusion

In buildings or installations not covered by legal requirements there is no defined system of emergency lighting. The factors that influence the choice of system have been touched upon in this article, but much experience has been gained by reputable battery manufacturers and it may be advisable to consult such a manufacturer if any special problems or circumstances exist.

The Tenth British Electrical Power Convention

The theme of this year's Convention—'Electricity and World Progress—Britain's Contribution'—afforded ample scope for a wide-ranging survey of many aspects of British electrical achievements, with considerable emphasis on nuclear power and on electrical exports.

In the following pages are summaries of the principal points of the Convention papers.

That the Convention owed much of its success to the personality of this year's President—Sir George Nelson, Bt, LLD, FCGI, DIC, MIMechE, MIEE—was evidenced by the whole-hearted acclamation of all the delegates after his Presidential Address, at the annual dinner, and at the Annual General Meeting, when Sir George, at the end of his year of office, invested the new president, Mr C. R. King, CBE, CompIEE, MInst F.

First Session: The Presidential Address

TAKING as his subject the theme for the Convention: 'Electricity and World Progress—Britain's Contribution', Sir George Nelson began by demonstrating the truth behind the claim that electricity brings better living to the world and presented some estimates based on discussions at the 1955 Geneva Conference on the peaceful use of atomic energy. In 1900 the world population was 1600 millions; in 1950 it had increased to 2400 millions, and he estimated that in the year 2000 it would be 3700 millions. In 1900 the world consumption of electricity was 9000 million units; in 1950 it had increased to 1,000,000 million units, and he estimated that in the year 2000 the consumption would be 9,000,000 million units. Expressing electricity as a percentage of the world total fuel consumption, the figures for the years 1900, 1950, and 2000 were 3, 21, and 47 per cent respectively. In 1950 industrial production was five times greater than it was in 1900, and he estimated that in 2000 production would be 810 times the 1950 figure.

Sir George said that Britain had made an unparalleled contribution to development in all parts of the world, and the electrical manufacturing industry was this country's second greatest exporting industry. The fundamentals of electrical science were laid by Michael Faraday, and in our own electrical industry the greatest early British contribution was undoubtedly the development of the steam turbine by Parsons, and this was still the basis of all thermal power stations—nuclear as well as fossil fuel fired. The steam turbine had been greatly developed and quite remarkable advances had been achieved. Britain had made important advances in the distribution of electricity. The total capacity in England and Wales now exceeded 24,000 MW, almost the whole of which was fed straight into the 275 kV super grid or the 132 kV grid, making this the largest interconnected supply system in the world. This had provided British engineers with a first-class development laboratory for switchgear, transformers, cables, and ancillary distribution equipment and for the whole technology of the distribution of electrical energy.

The lack of great hydro resources in this country often led foreigners to believe that Britain had played no significant part in the development of hydro-electric power. The falsity of this belief would be shown later in the Convention by a paper to be presented on British hydro-electric plant. There was a possibility that China and Russia might wish to purchase hydro-electric equipment from abroad and it was essential that they, and others, should recognize Britain's commanding position in this field.

The operation of the large network of electric trains in the Southern Region of British Railways had enabled British companies to develop traction equipment to an extent not possible anywhere else in the world and had provided British manufacturers with a steady base load for their work. The equipment supplied to foreign railways ran into many hundreds of millions of pounds.

Another major contribution which British industry had made to world progress had been in the export of electrical equipment to all parts of the world. Great Britain had been responsible not only for sending a large amount of machinery and equipment to overseas countries, but had also been involved in the execution of complete electrification projects. In Australia, New Zealand, South Africa, Rhodesia, and in many other countries, almost the whole of the generating and distribution equipment had been supplied from the United Kingdom.

Equipment and money were not everything, and the British electrical industry both in its manufacturing and supply aspects had contributed immensely to the establishment of industries in other countries by their willingness to train young men from many parts of the world in the operation and maintenance of the equipment produced in Britain. Through the FBI scholarships and the efforts of many individual companies there had been a constant stream of individuals to these shores seeking knowledge. He estimated that approximately 600 qualified electrical engineers returned from Britain to overseas territories every year to take up responsible positions, fortified with their knowledge and experience of British practice.

On behalf of the manufacturers Sir George paid tribute to the supply industry who had cooperated willingly in providing operating experience for their trainees. This had done much to facilitate the sale of British products overseas and was a vital contribution to the country's economy by the nationalized industries.

'Britain has made an important contribution to world progress through the application of electricity to im-

proving living standards,' said Sir George, 'but we cannot be content to rest upon our laurels. Our own standard of living is dependent upon sustaining our position in world trade, for it is impossible to support a population of 50 millions on the resources of this island alone. Unless we are prepared to face with equanimity the reduction of our population by half we have to continue and increase our efforts to export the goods and knowledge that the rest of the world needs.'

The world demand for electricity was steadily increasing, but we could not take the growth of our exports for granted. Three major factors which had to be taken into consideration were: the growth of local manufacture in countries which were formerly among our best markets; the development of export business by other countries; and financial and trading developments such as the recent creation of the European Common Market.

Although local industrialization might stop our exports of certain goods, the usual effect was to stimulate the exports of other goods. The growth of those factories involved demands for factory machinery, including electric motors and transformers; for electric power supplies; for generating and distributing equipment; for railways and other services.

The growth of local industries also led to the creation of towns, cities, and wage-earning populations with a powerful demand for amenities. All experience indicated that the demand for imports of electrical equipment tended to grow more rapidly in industrial countries than in non-industrial countries.

The formation of the European Common Market was of the greatest significance to us. If it went ahead and we were not associated with it through a free trade area or in some similar fashion we might find ourselves trading under very great handicaps in this most valuable market, and the Continental manufacturers operating within the common tariff wall with a home market of some 350 million people might well be able to outstrip us in size and productive capacity and so be able to compete with us in Commonwealth, Asiatic, and Latin American markets on more favourable terms. For this reason it was of the greatest importance that we keep in close touch with developments on the Continent in the coming years.

Some people had spoken as if the developments in Europe posed us with a choice between Europe and the Commonwealth. Personally he did not believe this to be so, for the true position was much more complex. The old pattern of exchanging British industrial goods for Commonwealth primary products was no longer acceptable. Commonwealth countries were seeking to produce their own industrial goods and to buy from a wider field. Furthermore, their primary industries were expanding more rapidly than the British market so that for many of them, New Zealand in particular, the European market offered a real attraction. All those factors pointed to the need for a closer integration of the Commonwealth and European economies, and we in Britain, who were still the leaders of the Commonwealth and who could be the leaders of the European community, had an essential part to play in bringing about this close integration. In such a European-Commonwealth economic association Great Britain would have a leading rôle to play as financier and as technical and scientific leader.

Second Session: 'The Development of Nuclear Energy for Electricity Supply in Great Britain'

Sir Christopher Hinton, KBE, FRS, MA, BSc, MICE, MIMechE, MIChemE

Chairman, Central Electricity Generating Board

In a closely reasoned review of Britain's nuclear power programme from its inception, through the subsequent stages of its development and a forecast of future trends, Sir Christopher Hinton presented a carefully balanced picture of optimism and caution. The former, because experience indicates that the first stage of our nuclear programme has been successful from every point of view; the latter because future trends underline the need for making the fullest possible use of the load generated by nuclear stations and for bringing down their cost, otherwise the magnitude of the programme will overtake its economics through the inability of nuclear reactors to carry peak loads at competitive costs.

Sir Christopher recalled that the United Kingdom's programme for the industrial use of nuclear power was published as a White Paper in 1955. It envisaged the construction by 1965 of 12 nuclear power plants having a total capacity of between 1500 and 2000 MW sent out. In fact the target which was aimed at was 1800 MW, equivalent to about 5 million tons of coal a year. The cost of power from these nuclear power plants was estimated to be about 0·6d per unit and this was stated to be approximately equal to the cost of producing electricity in the conventional power plants then being designed.

During the summer of 1956 there was considerable development of thought which led to a very great expansion of the programme.

One of the factors which started this trend of thought was the growth in size of reactor which was considered to be practicable, and the work of the consortia formed by industry to carry out the programme showed that the capacity of a 2-reactor station was likely to be of the order of 300 MW as compared with the 100-150 MW visualized in the White Paper. In March 1957 it was announced that the programme would be expanded, and the target for 1965 would be lifted from its initial level of 1500 to 2000 MW to a level of 5000 to 6000 MW. This decision was taken in spite of the fact that the economics of nuclear power looked slightly less favourable in 1956 than had been anticipated in the White Paper.

The reason for this unfavourable change in the economic assessment arose from a re-estimation of the

value which ought to be assigned to the by-product plutonium. During 1956 it was realized by the scientists that only limited burn-up of plutonium could be achieved in thermal reactors, which meant that its value as a fuel was less than expected and that it could be fully used as a fuel only in fast reactors. Meanwhile, it had become apparent that a great deal of work had to be done before the fast breeder system was evolved, and it was not unreasonable to reflect this in the plutonium credit.

The other factor which tended to reduce this credit was that America had decided to make considerable quantities of enriched uranium available through the International Agency.

These two factors together led to the conclusion that the plutonium credit allowed in the White Paper—about 0·35d per unit—was too high, and by the end of 1956 the published figure had been reduced to 0·07d per unit. This reduction was to some extent offset by the fact that the capital cost of the initial stations was rather lower than had been expected, but the published figures showed that the estimate of cost per unit sent out had risen from 0·6d to 0·66d. The large expansion of the programme which was adopted in 1957 brought with it another major problem. The cost of electricity produced in nuclear power stations had been based on the assumption that these power stations would work as base load stations with an annual load factor of 75 per cent. To use nuclear power stations in such a way was obviously wise because of their high capital cost, but it was a privilege which they could not enjoy indefinitely unless system load factors were considerably increased by, for example, three-shift working in industry. At present the load factor on the British electricity supply system was under 50 per cent and the minimum continuous load was only about 3000 MW. This occurred at night during weekends in the summer and was, in effect, the base load.

Need for Flexible Operation

A study of the estimated growth of the night load together with the forecast of the maximum nuclear capacity for the period 1960 to 1970 showed that up to 1966 the continuous load would always exceed the total capacity of the nuclear power stations, and these stations therefore would be able to operate as base load stations if the necessary transmission were provided. In this sense, flexibility of operation was a highly desirable but not essential characteristic for the plants to be commissioned by 1966. Beyond 1966, the total nuclear capacity would exceed the expected night load, and therefore, if the full output of these stations were available, they would be required to operate at reduced load during weekends in the summer.

After 1969, and again if the nuclear stations had an availability of 100 per cent, some of the stations would be required to reduce output at night during the week, in addition to weekends. Nuclear capacity in 1970 would have exceeded the continuous load on the system, and these stations, therefore, must be capable of operating at load factors of less than 75 per cent.

In those circumstances, nuclear power could only continue to compete if the capital cost per MW had been considerably reduced, and this reduction must have been achieved by 1966, because it was at that date that the plants would be ordered and designed.

Sir Christopher then indicated the way in which the cost of nuclear power might be expected to fall if development work was continued as successfully in the future as has been done in the past, pointing out that the reductions in capital cost achieved in the power plants now being built for the CEGB have been brought about by developments in conventional engineering applied to the Calder Hall design by the consortia. There was still room for further improvements of this sort which could reduce capital costs even more, but beyond a certain point, reduction in capital cost depended on raising the top temperature which could be achieved in the reactor. To do this, improvements in all parts of the reactor would be necessary, but the vital problem was in the development of the fuel elements.

The Future Outlook

Sir Christopher went on: 'We therefore come to the conclusion that although improvements in the performance of the gas-cooled graphite-moderated reactor arising from engineering developments can be expected over the next two or three years, the long term improvements arising from the achievement of a higher top temperature can only arise from major developments in technology involving the use of ceramic fuel elements canned in some such material as beryllium, and made in such a form that higher ratings and higher burn-ups can be achieved.

'If the research and development work which is necessary in order to bring down the capital cost of nuclear power plants is not complete and sufficiently well established by 1966/7, when orders will have to be placed, then there can be only one of two results. Either we shall have to proceed with the installation of nuclear power plants which will produce electricity more expensively than it could be produced from conventional plants, as would be required if there were to be a severe shortage of coal, or alternatively, we shall have to swing back towards the use of conventional power plants.'

Because of the financial restrictions imposed last year, the attainment of the target of 5000 to 6000 MW of nuclear power by 1965 might be delayed by about twelve months. Even so, in 1965, the annual programme was expected to amount to some 1400 MW and this rate of installation might continue through the late 60s. If all went well, nuclear capacity by 1970 would have reached the base load, and after that time, if the same rate of installation continued, a proportion of the nuclear stations would have to work at reduced load factors.

If flexibility of operation could not be built into these nuclear stations, and if their capital cost could not be reduced to the point where they could generate electricity as cheaply as conventional plants on a reducing load factor, then instead of continuing to install plant at a rate of not less than 1400 MW per annum the figure might fall to 300/400 MW to match the probable growth in the base load. In order to make good the deficit, the amount of conventional plant would have to be increased to about 2000 MW per annum. The only alternative would be to continue to install nuclear plants even though generation costs would be higher.

proving living standards,' said Sir George, 'but we cannot be content to rest upon our laurels. Our own standard of living is dependent upon sustaining our position in world trade, for it is impossible to support a population of 50 millions on the resources of this island alone. Unless we are prepared to face with equanimity the reduction of our population by half we have to continue and increase our efforts to export the goods and knowledge that the rest of the world needs.'

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Sir Christopher Hinton, KBE, FRS, MA, BSc, MICE, MIMechE, MIChemE

Chairman, Central Electricity Generating Board

In a closely reasoned review of Britain's nuclear power programme from its inception, through the subsequent stages of its development and a forecast of future trends, Sir Christopher Hinton presented a carefully balanced picture of optimism and caution. The former, because experience indicates that the first stage of our nuclear programme has been successful from every point of view; the latter because future trends underline the need for making the fullest possible use of the load generated by nuclear stations and for bringing down their cost, otherwise the magnitude of the programme will overtake its economics through the inability of nuclear reactors to carry peak loads at competitive costs.

Sir Christopher recalled that the United Kingdom's programme for the industrial use of nuclear power was published as a White Paper in 1955. It envisaged the construction by 1965 of 12 nuclear power plants having a total capacity of between 1500 and 2000 MW sent out. In fact the target which was aimed at was 1800 MW, equivalent to about 5 million tons of coal a year. The cost of power from these nuclear power plants was estimated to be about 0·6d per unit and this was stated to be approximately equal to the cost of producing electricity in the conventional power plants then being designed.

During the summer of 1956 there was considerable development of thought which led to a very great expansion of the programme.

One of the factors which started this trend of thought was the growth in size of reactor which was considered to be practicable, and the work of the consortia formed by industry to carry out the programme showed that the capacity of a 2-reactor station was likely to be of the order of 300 MW as compared with the 100-150 MW visualized in the White Paper. In March 1957 it was announced that the programme would be expanded, and the target for 1965 would be lifted from its initial level of 1500 to 2000 MW to a level of 5000 to 6000 MW. This decision was taken in spite of the fact that the economics of nuclear power looked slightly less favourable in 1956 than had been anticipated in the White Paper.

The reason for this unfavourable change in the economic assessment arose from a re-estimation of the

value which ought to be assigned to the by-product plutonium. During 1956 it was realized by the scientists that only limited burn-up of plutonium could be achieved in thermal reactors, which meant that its value as a fuel was less than expected and that it could be fully used as a fuel only in fast reactors. Meanwhile, it had become apparent that a great deal of work had to be done before the fast breeder system was evolved, and it was not unreasonable to reflect this in the plutonium credit.

The other factor which tended to reduce this credit was that America had decided to make considerable quantities of enriched uranium available through the International Agency.

These two factors together led to the conclusion that the plutonium credit allowed in the White Paper—about 0·35d per unit—was too high, and by the end of 1956 the published figure had been reduced to 0·07d per unit. This reduction was to some extent offset by the fact that the capital cost of the initial stations was rather lower than had been expected, but the published figures showed that the estimate of cost per unit sent out had risen from 0·6d to 0·66d. The large expansion of the programme which was adopted in 1957 brought with it another major problem. The cost of electricity produced in nuclear power stations had been based on the assumption that these power stations would work as base load stations with an annual load factor of 75 per cent. To use nuclear power stations in such a way was obviously wise because of their high capital cost, but it was a privilege which they could not enjoy indefinitely unless system load factors were considerably increased by, for example, three-shift working in industry. At present the load factor on the British electricity supply system was under 50 per cent and the minimum continuous load was only about 3000 MW. This occurred at night during weekends in the summer and was, in effect, the base load.

Need for Flexible Operation

A study of the estimated growth of the night load together with the forecast of the maximum nuclear capacity for the period 1960 to 1970 showed that up to 1966 the continuous load would always exceed the total capacity of the nuclear power stations, and these stations therefore would be able to operate as base load stations if the necessary transmission were provided. In this sense, flexibility of operation was a highly desirable but not essential characteristic for the plants to be commissioned by 1966. Beyond 1966, the total nuclear capacity would exceed the expected night load, and therefore, if the full output of these stations were available, they would be required to operate at reduced load during weekends in the summer.

After 1969, and again if the nuclear stations had an availability of 100 per cent, some of the stations would be required to reduce output at night during the week, in addition to weekends. Nuclear capacity in 1970 would have exceeded the continuous load on the system, and these stations, therefore, must be capable of operating at load factors of less than 75 per cent.

In those circumstances, nuclear power could only continue to compete if the capital cost per MW had been considerably reduced, and this reduction must have been achieved by 1966, because it was at that date that the plants would be ordered and designed.

Sir Christopher then indicated the way in which the cost of nuclear power might be expected to fall if development work was continued as successfully in the future as has been done in the past, pointing out that the reductions in capital cost achieved in the power plants now being built for the CEGB have been brought about by developments in conventional engineering applied to the Calder Hall design by the consortia. There was still room for further improvements of this sort which could reduce capital costs even more, but beyond a certain point, reduction in capital cost depended on raising the top temperature which could be achieved in the reactor. To do this, improvements in all parts of the reactor would be necessary, but the vital problem was in the development of the fuel elements.

The Future Outlook

Sir Christopher went on: 'We therefore come to the conclusion that although improvements in the performance of the gas-cooled graphite-moderated reactor arising from engineering developments can be expected over the next two or three years, the long term improvements arising from the achievement of a higher top temperature can only arise from major developments in technology involving the use of ceramic fuel elements canned in some such material as beryllium, and made in such a form that higher ratings and higher burn-ups can be achieved.

'If the research and development work which is necessary in order to bring down the capital cost of nuclear power plants is not complete and sufficiently well established by 1966/7, when orders will have to be placed, then there can be only one of two results. Either we shall have to proceed with the installation of nuclear power plants which will produce electricity more expensively than it could be produced from conventional plants, as would be required if there were to be a severe shortage of coal, or alternatively, we shall have to swing back towards the use of conventional power plants.'

Because of the financial restrictions imposed last year, the attainment of the target of 5000 to 6000 MW of nuclear power by 1965 might be delayed by about twelve months. Even so, in 1965, the annual programme was expected to amount to some 1400 MW and this rate of installation might continue through the late 60s. If all went well, nuclear capacity by 1970 would have reached the base load, and after that time, if the same rate of installation continued, a proportion of the nuclear stations would have to work at reduced load factors.

If flexibility of operation could not be built into these nuclear stations, and if their capital cost could not be reduced to the point where they could generate electricity as cheaply as conventional plants on a reducing load factor, then instead of continuing to install plant at a rate of not less than 1400 MW per annum the figure might fall to 300/400 MW to match the probable growth in the base load. In order to make good the deficit, the amount of conventional plant would have to be increased to about 2000 MW per annum. The only alternative would be to continue to install nuclear plants even though generation costs would be higher.

Third Session: **'The Development of Nuclear Energy for Electricity Supply Overseas'**

Sir Claude Gibb, KBE, DSc, FRS

Chairman and Managing Director, C. A. Parsons & Co Ltd

Starting from the thesis that there appears to be ample evidence that national prosperity increases with increases of electricity consumption per head, and that this applies throughout the world with but few exceptions, Sir Claude pointed out that a study of world reserves of coal and oil showed them to be quite incapable of meeting alone the fuel demands which would be made if electricity consumption continued to grow as it had during the past fifty years. The requirement for some additional or supplementary fuel was with many nations to-day and would be with many others within ten or twenty years.

'The name Calder Hall is known throughout the world and Britain gained much badly needed prestige by the brilliance of conception and its successful design, construction and operation,' said Sir Claude. 'The fact that many of the considerations leading to the final design decisions were economic, and some of expediency dictated by availability of supplies and materials, in no way detracts from the final result, which is that the graphite moderated gas cooled reactor is the most economic type available in the world to-day for large power outputs.'

The outstandingly successful operating experiences of Calder Hall had enabled many valuable advances in design and operation to be made in the subsequent nuclear stations now being built. Considerable reductions in capital cost per kW installed had already been made, and the possibilities of still further reductions could now be seen as the result of further research. Probably the biggest single factor in capital cost reduction was the increase in reactor output.

He then specified what may be accepted as large, medium, and small, when applied to electricity outputs, pointing out that five years ago in Britain 60 MW was a large unit; to-day it is medium, and in a further five years will be regarded as a small unit. He therefore adopted the following quite arbitary sizes which, in the short time of a decade, will need adjusting upwards:

Small reactors: those with a net electrical output not exceeding 20 MW.
Medium reactors: those between 20 MW and 100 MW.
Large reactors: with a net electrical output exceeding 100 MW.

On capital cost, Sir Claude gave the following figures. Modern hydro-electric power stations cost between £100 and £150 per kW installed, and in most countries require long and costly transmission lines. However, hydro fuel costs, station operating and maintenance costs are extremely small; moreover, the life of hydro stations is frequently reckoned as between fifty and eighty years, so depreciation and/or sinking fund charges are also low. Thus the high capital cost spread over such a long period rarely amounts to a unit charge as high as that of a coal-fired station costing a half or even less per kW installed but arbitrarily given a life of about twenty-five years. A large capacity coal-fired station—say, 600 to 800 MW—to-day would cost between £50 and £55 per kW installed.

A large nuclear station with two reactors and an output of 600 MW would cost some £110 per kW installed, exclusive of the first charge of fuel. It would have a fuel cost per kW approximately one half that of a modern coal-fired station at British coal prices. But as British coal is between three and four times as costly as in many power stations in the USA, a modern nuclear station in Britain would have a capital cost about double, and a fuel cost almost double, that of the more fortunate power stations in the USA—giving total generation costs about double that of, say, the Kingston power station of the Tennessee Valley Authority. Obviously there could be no case for a nuclear power station there until coal costs increased fourfold.

And so it would be in some other parts of the world: Venezuela with its apparently inexhaustible supplies of natural gas; Victoria, Australia, with its 2000 years' reserves of brown coal.

But in other countries, traditional fuels are scarce, or reserves are limited and must be supplemented.

World coal and oil reserves were great but were not inexhaustible, and the projected increases in world energy demands showed clearly how necessary it was to develop as quickly as possible alternative ways of providing that additional energy, which almost entirely must be in the form of electricity.

Touching on the essentials for any system of electricity generation, Sir Claude stressed the reliability aspect, since if there are doubts on this score, standby plant must be provided at increased capital cost which must be charged against the unreliable plant. This was an important factor in the choice of a reactor for a public supply system. Safety was inherent in reliability and played an important part in deciding on the siting of a nuclear power station.

A nuclear power station employing gas-cooled, graphite-moderated reactors complied fully with the essentials for electricity generation. If correctly designed, it was inherently safe, and since provision could be made for changing fuel elements while on full load, it could be given availability of a very high order—at least equal to any coal- or oil-fired station. With fission product detection applied to every channel, any minor defect in a fuel element was readily located, and with on-load fuel charge and discharge equipment, the defective elements were quickly and simply changed without shutting down the reactor or even reducing the load on the power station.

This ability to detect and rectify while on load was regarded in Britain as an essential feature of design, and would be so regarded by most experienced power plant operators. The application of the on load charge/discharge principle to any other than a gas-cooled reactor

introduced formidable engineering problems, for which an elegant and acceptable solution had yet to be found.

Only Britain of all nations of the world, said Sir Claude, had committed itself to a large-scale nuclear power programme as a firm power producer to supplement coal- and oil-fired generating stations necessary to meet the continuously expanding demand for electricity. Britain had had the need for that supplementing fuel but had also had the courage, the ingenuity, and the skill to develop it and apply it on a large scale. Calder Hall and its successors had given Britain a commanding lead in the new era of nuclear power, but were we going to be able to maintain that lead?

Britain's need for a supplementary fuel was so great that research and development on a very large and adequate scale was proceeding both within the Atomic Energy Authority and in industry. Much of the research and testing necessary for that development required equipment on a scale and of a cost that was quite beyond the ability of private industry to provide for itself at the present stage of world nuclear demand. Industry was already spending huge sums annually on research and engineering design studies, and would find this expenditure crippling unless orders for nuclear equipment were received on a scale and at a price which would enable that expenditure to be recovered.

The scale of effort required to develop a new type of reactor was such that inevitably it had been necessary with our limited resources in manpower and money to avoid spreading them over too wide a field of potential or possible reactors, so delaying the finalizing and construction of any one type. This had led to a concentration of the major effort on large output schemes such as were required for Britain and would be suitable for highly developed countries overseas. Italy, France, Germany, Holland, Canada, India, Russia, Australia—all have integrated electricity supply systems of a magnitude able to justify the installation of reactors exceeding 100 MW net electrical output, provided that the electricity costs from such nuclear stations did not exceed those of traditional fuelled stations.

In many of those highly industrialized European countries, many of the components for a nuclear station were either already manufactured in that country or could be made with limited adaptation of their existing industrial equipment. Extremely detailed information about the design and construction of Calder Hall had been given to the world, and much information on the designs of the four new British nuclear stations had already been published. Hence the main thing British industry had to sell in highly industrialized countries was experience in design details, in construction, and, shortly, in operating experience additional to that already obtained from Calder Hall. But it was just that detailed experience which could, and almost certainly would, enable savings of many millions of pounds to be made on each nuclear station built.

Sir Claude then dealt in detail with the considerations affecting small and medium-sized reactors; the effect of national policy on reactor selection; an analysis of the characteristics, advantages, and disadvantages of the four possible moderators and four systems of cooling which may be used with thermal reactors, reaching the conclusion that, for small and medium power outputs, it was likely that a gas-cooled, heavy water moderated, slightly enriched uranium fuelled reactor offered the greatest promise of early development. It was unlikely, he said, that there would be general agreement with this view, but if it were accepted that on-load fuel charging was essential, then the gas-cooled reactor must take first place on engineering grounds.

Higher fuel temperatures; higher burn-up rates; longer periods of irradiation; greater heat transfer rates from fuel to coolant; techniques for the production and fabrication of new metals and alloys with better qualities for nuclear application—these were the directions in which research and development were proceeding to improve large output reactors, and upon their solution would depend the speed with which efficient and economic medium and small output reactors were produced.

Nuclear power stations demanded a standard of technical competence in the operating staff far above that needed in an orthodox oil-, gas- or coal-fired station. Only a nation which was actually operating nuclear stations could provide the training and experience so essential to satisfactory or indeed safe performance. Britain was in that fortunate position and able to provide that essential training.

Fourth Session: 'Britain's Part in Electrical Development Overseas'

H. J. Beard, BA, MIEE

Partner, Merz and McLellan, Consulting Engineers

Mr Beard began his paper by outlining the many ways in which Britain has contributed, and is continuing to contribute, to electrical development overseas: by fundamental research; by providing technical manpower and training facilities; by providing advice and consulting services on all aspects of electricity supply and utilization; and by financial assistance—the latter comprising the investment of both privately owned and Exchequer funds in projects in Commonwealth countries through direct investment transactions on the London market

(including the Commonwealth Development Finance Co); through the Colonial Development Corporation, the Export Credits Guarantee Department, and by way of sterling releases to the World Bank. As some measure of the United Kingdom effort, the speaker put the approximate total of average investment in the whole Commonwealth over the years 1953/56 at nearly £200 million a year. It had been unofficially estimated that in the ten years from 1946 to 1956, 70 per cent of the external capital invested in the sterling Commonwealth came from the United Kingdom, compared with 15 per cent from the USA, 10 per cent from the World Bank, and 5 per cent from other sources.

Turning to electrical exports, Mr Beard said that our position in the export markets of the world was another indication of Britain's part in electrical development overseas.

In 1957 our electrical exports reached a new peak of £279 million, which figure did not include electrical equipment which is directly coupled to other engineering plant. Taking this into account would have raised the total to £300 million or more. After allowing for the reduced value of money, the volume of our electrical exports had doubled since 1947 and increased fourfold since 1938. There had been an overall increase in world electrical exports of 54 per cent over the last five years. The United States increase of 47 per cent was not far below the average, and Western Germany with 183 per cent had had the largest increase. Britain's increase and the increase of other countries were both below the average at 28 per cent and 37 per cent respectively. This lower rate of increase was reflected by the gradual reduction in our share of the world electrical exports from 28·1 per cent in 1952 to 23·2 per cent in 1957. In other words, the increase in our exports had not been sufficient to retain our proportion of the world market, and the substantial increase in Western Germany had been at the expense of this country and the other countries, including the United States.

The electrical industry in Britain had made strenuous efforts to expand its production to satisfy the many and increasing demands it has had to meet, and he quoted figures which showed that UK electrical exports were 22 per cent of total production compared with 20 per cent in Western Germany and 6 per cent in USA.

In Britain, said Mr Beard, there were a number of firms of consulting engineers who specialized in electrical and mechanical problems associated with electricity power supply and who for many years had been intimately connected with the electricity supply industry both in Britain and overseas. Apart from consulting services, advice on technical problems was provided by Britain in many ways and in many different fields. Very considerable help was given to electricity undertakings overseas in the course of ordinary commercial transactions for the supply of plant and equipment and through the contacts between the specialists of exporting firms and engineers overseas. The dissemination of our technical knowledge in this way was a vital part of the effort put into our export drive.

Mr Beard referred to a few of the important and interesting contracts which Britain had secured in recent years, to illustrate the range and diversity of the contribution that British manufacturers could make and were making towards world electrical development. One of the most significant contracts was obtained in 1957 for the construction in Italy of a 200 MW nuclear power station with a Calder Hall type reactor. Two 120 MW turboalternators were being supplied to Poland, while other contracts included three 105,000 hp water turbines and alternators, together with 132 kV and 220 kV transformers and switchgear for Belesar power station in Spain, and a large number of air-blast circuit-breakers for various projects in that country. Hydraulic plant and electrical equipment had also been supplied for other power stations in Spain, while a 60 MW horizontal water wheel alternator had been supplied for the Aura power station in Norway.

Generating plant and switchgear had been supplied to the Athens Piraeus Electricity Company, and more than 300 miles (483 km) of 66 kV and lower voltage overhead lines had been constructed in Cyprus. Cables and switchgear worth more than £1 million and some small turboalternators had been ordered by the USSR.

British manufacturers had obtained the orders for the major part of the plant and equipment for the first power station at Kariba, Rhodesia, which includes six 140,000 bhp water turbines and 100 MW alternators, together with the 330 kV switchgear, transformers, and oil-filled cables. In regard to this project, Mr Beard said the success achieved by Britain's engineering industry in the face of fierce international competition was indicated by the fact that Britain was supplying over 90 per cent of the power plant equipment and 74 per cent of the 330 kV transmission system equipment.

The Owen Falls hydro station in Uganda with eight 15 MW machines was the first large Kaplan turbine installation in Africa, and was of interest as an example of the rapid growth of load once a reliable source of power was established in undeveloped territory.

Many other contracts were mentioned by Mr Beard for projects in Australasia, Canada, and the USA, while a number of contracts in the Middle East, if less impressive as regards size, had several interesting features.

Mr Beard said that with the continued electrical expansion throughout the world the industrialization of the less developed countries was inevitable, and the pattern of our exports must be adjusted to fit in with the changing requirements. These adjustments would involve reductions in certain of our export fields, but we must recognize that the expansion of industrial activity overseas would increase the demand for the more specialized types of equipment as well as increasing the need for generating plant and high voltage transmission and distribution equipment. It was, however, essential that Britain must be able to meet any demands which might arise for the supply of equipment and services, and he was certain that ways and means to meet the challenge would be found, in spite of extensive commitments at home in connexion with the extension and modernization of our industries and public utilities.

Fifth Session: **'British Hydro-Electric Plant and World Power Requirements'**

J. C. Beverley, MA, AMIMechE, AMIEE; E. G. Teasdale, BA; A. Wilmot, BScTech, DIC, AMIMechE

All three Authors are with the English Electric Co Ltd

The length of this very comprehensive paper (some twenty thousand words, with numerous tables and illustrations) makes drastic condensation inevitable, but the following summary covers the main points made by the authors, who presented the paper jointly.

They began by pointing out that Britain entered the hydro-electric field at a relatively late stage compared with other countries. Nevertheless, small water turbines had been made and operated in Britain for over a century, and one of the early ones—made by a British firm that has since manufactured some thousands of water turbines for all parts of the world—is still running after a hundred years of use.

The section of the paper which high-lighted the achievements of British manufacturers in the water turbine and water turbine-driven alternator fields showed clearly how effectively British endeavour had placed this country in the forefront of hydro-electric engineering. To-day this accumulated experience is being used to assist other countries of the Commonwealth also to develop in the hydro-electric field.

The authors then dealt with the British influence on modern water turbine developments, taking 1920 as the starting-point of the modern era when the increased world demand for power stimulated the growth of the water turbine business in Britain. In 1922, units of 30,000 hp were first ordered; at the present time units of 200,000 hp are under construction. The cumulative total of orders for water turbines placed in Great Britain since 1920, including turbines designed in this country and manufactured overseas, amounted to 15 million hp.

In the markets of special interest to British manufacturers, the large capacity turbine is used to only a small extent; thus, although many of them had been built, the efforts of the British manufacturers had been devoted mainly to the development of the Francis and Kaplan turbines.

Simultaneously with the growth in size and output, there had been a substantial increase in the head range. Before 1945 there were relatively few examples of Francis turbines operating on heads over 800 ft (244 m), but in the last ten years or so this maximum head had been approximately doubled, and British manufacturers had made important contributions in the field of high-head Francis turbines. As examples, three stations (one each in Canada, Australia, and Tasmania) have been or are being equipped with Francis turbines operating under maximum heads of 875 ft (267 m), 1095 ft (334 m), and 935 ft (285 m) respectively. The Canadian turbines, built in Canada to designs produced in this country, had developed maximum outputs of 200,000 hp in service and are the most powerful turbines yet in operation in the world.

The Kaplan turbine had also been extensively developed, with a great increase in physical dimensions and a substantial raising of the upper head limit. One such turbine installed in Scotland operates under a maximum head of 181 ft (55 m). The ten Kaplan turbines now being built for the Priest Rapids power station in the USA, each capable of 131,000 hp maximum output and with a runner diameter of 23 ft 8 in (7·2 m), were the largest in physical dimensions so far built in this country, although they by no means represented the maximum that could be built.

The relatively new tubular type of turbine was especially suitable for low-head run-of-river schemes, as it resulted in appreciable savings in the cost of civil engineering works. The first of this type to be built in this country is being installed in Scotland and will develop 145 hp under a head of 19 ft (5·8 m). Similar units to have outputs up to 14,000 hp are at present under consideration for other schemes in Scotland, and should the Severn Barrage scheme ever be proceeded with, units of this type would probably be adopted.

Another notable development was a turbine to operate above the economic head range of the Kaplan turbine and to give a flat efficiency curve over a wide range of heads and outputs. This is the Deriaz turbine—a Francis turbine with movable blades, named after its inventor, Mr Paul Deriaz, the Chief Designer of one of the British water turbine manufacturers. This type of turbine could be used for heads up to about 600 ft (183 m) and had already been used successfully as a reversible pump turbine in the Sir Adam Beck No 2 pump storage power station in Canada, where six units have been installed. Each unit operates over a head range from 45 to 90 ft (13·7 to 27·4 m) with a maximum output as a turbine of 45,000 hp and with a maximum discharge of 5040 cusecs requiring an input of 55,000 hp as a pump.

The authors then dealt in detail with pumped storage and reversible pump turbines, pointing out that the Deriaz turbine was very suitable for the lower head pump storage schemes since the runner is of the mixed flow type. Furthermore, as the runner vanes are movable, the gate apparatus could be dispensed with in certain cases, but of particular importance was that, with the movable vanes, quantitative regulation of the pump as well as of the turbine could be obtained. In this country a pumped storage scheme in Scotland is operating as a part of a hydro-electric scheme, and this is now being followed by the Ffestiniog scheme in North Wales which, with an installed capacity of 300 MW, will be the largest

pumped storage scheme in the world. Here separate pumps and turbines are necessary because of the high water head, which amounts to a maximum of 1062 ft (324 m) when pumping and 1020 ft (311 m) when generating.

The paper then discussed manufacturing and fabricating techniques and referred to the increased use of welded steel plate instead of castings for the majority of components—a practice in which this country is now in advance of the rest of the world. British water turbine manufacturers were prominent in adopting welded steel spiral casings, initially in place of riveted construction, as far back as 1826, and more recently in place of cast steel for even the higher head applications. In both applications welded casings have shown appreciable savings.

Fabrication had since been gradually developed for other components—first, for turbine top covers and regulating rings, and then for stay rings—the latest of which are 37 ft 6 in (11·4 m) in diameter and weigh 100 tons. Since 1945, fabrication has been further extended to include the runner itself—the most complex and important part of a Francis turbine.

Other notable design features mentioned by the authors were the recent development of the self-lubricating bearing and the carbon-ring gland—which was first successfully used by a British manufacturer about twenty years ago and has been in regular use ever since.

Developments in butterfly valves were reviewed, and some notable British achievements in smooth-bore valves for higher head installations were mentioned—perhaps the most outstanding being the eight 7 ft 9 in (236 cm) bore straight-flow valves designed in this country and manufactured in Canada for the Quebec Hydro-Electric Commission. They operate under a maximum head of 875 ft (267 m) and in service have closed with ease against flows equivalent to 200,000 hp.

The considerable growth in power supply systems with extensive interconnexion has introduced the need for a turbine governor which will act as a power regulator for the generating unit, and one British manufacturer had developed an electro-hydraulic governor for this purpose. Its performance had been so satisfactory in service that five have now been ordered for the control of five 200,000 hp turbines under construction for the Chute-des-Passes power station in Canada.

The paper referred to the extensive use of model tests to predict the performance of the full-size turbine, and these were being increasingly accepted for guarantee purposes as an alternative to site efficiency tests. Extensive laboratory facilities exist in this country for such tests.

Development in water turbines has demanded corresponding progress in the alternators which they drive, and these demands had been met by British manufacturers by many important design developments. Considerable attention had been paid, for example, to reducing the weight and the cost of the alternator, even though the electrical characteristics imposed upon it are often more onerous than in the past due to long transmission lines and interconnected systems. The steps taken included the increasing use of iow-hysteresis-loss steel for certain alternator stators, and redesign of the alternator rotor to eliminate as much weight as possible from the hub.

The alternator designer had also been faced with the problem of supplying a thrust bearing to take not only the weight of the alternator and turbine rotating parts but, in addition, the hydraulic thrust from the turbine runner, which in the case of a Kaplan turbine is particularly large. Typical values of recent bearing loads were quoted, ranging from 310 to 1740 tons.

Other special design features had been introduced to reduce not only the cost of the machine itself, but also the cost of the civil works by achieving a reduction of the overall height of the installation.

Increasing use had been made in the last ten years of induction generators rated at anything from 20 to 5000 kW. They can develop useful power from compensation water; they need no voltage regulator or excitation equipment and no turbine governor; they may therefore cost some 30 per cent less than a normal governed turbine with a synchronous alternator.

Just as special governing is required for large water turbines, so new voltage regulators had been developed for the alternators. Incorporating either magnetic amplifiers or transistors, they give very high rates of response with flexibility for different operating conditions.

With the advent of the hydro-electric station as a major generating unit in an important system, greater emphasis had been placed on control equipment, both for attended stations and for remote or automatic control of unattended stations. British industry had been in the forefront of the development of the necessary electrical schemes for many countries in the world.

The paper dealt briefly with the special problems arising in the transport and erection of hydro-electric plant and referred to the close cooperation necessary between the various groups of engineers associated with any project.

The future of hydro-electric development was surveyed, and it was clear from the development which had taken place since 1945 and the constant pressure of world energy demand on the available resources that the demand for hydro-electric power would continue at an increasing rate. A great part of the world's potential water power still remains to be developed, and the authors estimated that the annual demand in the free world for new hydro-electric plant in three years' time would be 10,500 MW. During the forty years in which the larger water turbines had been manufactured in Britain, British engineers had been closely associated with almost every major advance in design and constructional techniques. While there had been no corresponding fundamental change in alternator design, so that neither Britain nor any other country could claim to have led the way, British electrical engineers had successfully taken part in solving all those problems introduced by the really spectacular increases in output and physical dimensions and by the adoption of new methods of mechanical construction.

At the present time, therefore, it was true to say that British industry is able to supply and to put into operation any type and size of hydro-electric plant which purchasers anywhere in the world are likely to require. British consulting engineers were equipped to carry out any investigations into proposed schemes and to undertake any other tasks that might be required of them in connexion with hydro-electric projects.

Sixth Session: **'The Development of the Electrically Equipped Kitchen'**

J. I. Bernard, MIEE

Director and Secretary, British Electrical Development Association

'Electrical appliances are the key to the modern kitchen, which is clean, convenient, and easy to run', said Mr Bernard. He described them in some detail in the first part of his paper; the second part showed how they could improve existing kitchens; and the third part showed what could be done when starting with a clean slate to build an ideal kitchen in a new house or flat.

The means of cooking still occupied pride of place in the kitchen, and there were now over 3 million users of electricity for this purpose. Given reasonable freedom from financial restrictions, this number should increase rapidly in the future.

Improved materials and methods of manufacture had proved particularly valuable in securing the better performance now available from electric boiling plates, which now do not need to have a polished reflector underneath them. Manufacture had also been simplified by the widespread adoption of infinitely variable energy regulators which permitted single-circuit plates to be used, and some of the newer types improved performance still further by imposing higher than normal voltage for a short initial period.

Grill-boilers represented a successful compromise in the smaller cookers, but for larger cookers the recently introduced 'eye-level' grills would probably prove more popular.

Improvements in oven design had been mainly in increased loading, and reduced weight of metal and lagging to give still quicker heating-up.

The most striking development had undoubtedly been the introduction of automatic time control, which made a strong appeal particularly to the younger housewives.

On the score of cost, Mr Bernard showed that, as the price of electricity had advanced much less than that of any other fuel, cooking by electricity is now much less expensive than by any other method.

The slow growth in the use of refrigerators in Great Britain could be ascribed, he said, to purchase tax and credit squeezes (the former now somewhat relaxed), and to the infrequent occurrence of spells of hot weather.

That the design of British-made refrigerators is as good as any, and better than most, was proved by the large proportion exported, but if the home market were larger, production costs would be reduced and a still greater number could be exported.

Great advances had been made in design and construction details of compressor type refrigerators, although the simple absorption type continued to hold its own for the smaller cabinets, and improvements had been made in the efficiency of this type as well. Since in most British kitchens floor space is so limited, the newest refrigerators were designed to be used as table-top models, or built into a kitchen cabinet, or hung on the wall at eye level.

In new homes and flats, and especially in old houses which had been converted, a refrigerator of adequate size was a much better investment than the bricks and mortar and valuable floor space which would otherwise go to the making of a larder.

Adequate supplies of really hot water were essential, and an electric water heating installation was the ideal means. Self-contained electric water heaters, which avoided undue radiation losses, were readily adapted to existing pipe-work; the small sink models were unobtrusive and attractive in appearance, while the larger 20-gallon (91-litre) size would fit neatly in a corner under the draining board.

The most popular method of water heating by electricity was an immersion heater fitted in the existing hot water storage tank, because the capital cost was so much less than a self-contained heater of the same capacity. Proper lagging to prevent heat loss was, however, essential; for example, the radiation loss of a 30-gallon (136-litre) tank maintained at 160 deg F (71 deg C) without lagging would be 85 units a week, but properly insulated with 3 in (7·6 cm) thick glass or slag wool, the standing loss was reduced to only 8 units a week.

Since the war, progress in the manufacture of home laundry appliances had been tremendous; the increase in the number of washing machines from 2 per cent of households in 1947 to 23 per cent in 1957 had been probably the most noteworthy development in the domestic appliance business. The most recent addition to the home laundry was the spin dryer, either incorporated in the washing machine instead of a wringer, or more usually as a separate appliance.

Ironing machines, both of the rotary and the press type, were now available, and the latest models of hand iron were lighter in weight (with a compensating higher loading) and therefore easier to use.

Much invention and years of development had now resulted in efficient dish-washing machines, and a further refinement was the electric garbage disposer for pulverizing all kitchen refuse.

Mr Bernard listed the many portable appliances available—food mixers, kettles, toasters, and so on; stressed that a suitable form of electric heating should always be provided for the kitchen, and that—obviously—adequate socket outlets were essential.

Turning to the improvement of existing kitchens, the speaker said that experience with the EDA Kitchen Planning Service had shown that in a distressingly high proportion of them an efficient labour-saving layout was impossible, but much could be done by re-equipping them with modern electrical appliances. There was to-day such a wide range of sizes and types that appliances could be fitted into what had hitherto been regarded as impossible or inadequate spaces.

He then gave several examples of typical kitchens, showing the 'before' and 'after' arrangements and the great improvement thereby effected. Finally, he gave several examples of the planning of new kitchens, and referred to the volume of *Electrical Data for Architects* issued by the EDA.

New Control System for the British National Grid

WITH the development of a new and highly advanced telecommunications project, the British electricity supply system becomes the most modern, as well as the largest, generation and distribution system under unified control in the world. The coordination of some 260 power stations with an aggregate capacity of 22,000 MW (30 million hp) and 350 main electricity distributing centres (grid switching stations) as a single operational unit represents a major administrative and engineering achievement, and the new control system now in successful operation is the culmination of some twenty-six years of highly specialized experience.

When the British National Grid system was first established in 1932, control was centralized in seven districts, each with a combined grid control centre and district headquarters, and connected to the principal base load stations and switching substations—at that time owned by the various power companies and local authorities—in its own regional network.

With the steady expansion of the grid, improvisations and modifications had to be repeatedly made to individual installations—often at disproportionate cost in terms of money and engineering effort. Matters came to a head when the supply industry was nationalized in 1948 and it became necessary to provide communication facilities between the generating stations and the respective headquarters of the fourteen generation divisions of the British Electricity Authority which replaced the earlier CEB districts. The seven grid control areas, however, remained unchanged.

NORTH OF SCOTLAND HYDRO-ELECTRIC BOARD
GLASGOW
SOUTH OF SCOTLAND ELECTRICITY BOARD CONTROL
NEWCASTLE GRID CONTROL AREA
LEEDS GRID CONTROL AREA
MANCHESTER GRID CONTROL AREA
BIRMINGHAM GRID CONTROL AREA
THAMES NORTH GRID CONTROL AREA
NATIONAL CONTROL CENTRE
BRISTOL GRID CONTROL AREA
THAMES SOUTH GRID CONTROL AREA

Grid Control areas, 1958: CEGB, SSEB and NSHEB

Accordingly, the British Electricity Authority decided in 1949 to re-equip the grid control networks, then more than fifteen years old, with a standard system of general indicating, telephone, and telemetering equipment which could be extended from time to time to suit changing conditions.

Expansion since then has been—and still is—continuous, and the Central Electricity Generating Board is today supplying a load many times greater than pre-war, or even ten years ago, from a miscellany of power stations—of which some are old and many are new, with capacities ranging from 100 MW or less to 500 MW, and with thermal efficiencies varying from about 10 to 30 per cent or better. Moreover, fuel costs necessarily vary widely according to the distance of the power station from the coalfields (the ratio may be as much as 2 to 1 between a station in the Midlands and one in, say, the West Country). With all these variables, it is not surprising that the Board's fuel costs of generation range from approximately 0·3d a unit for the best station up to about 2d a unit for the worst.

It is therefore a matter of paramount importance—both to the Board and to the consumer—to apportion the load between the 260 power stations so that those which can generate at the lowest cost are used to the maximum extent, while those with the higher generating costs are used as little as possible.

The control organization is in full operation throughout the twenty-four hours of every day—checking generating costs, planning load programmes for each 3-hour period, and issuing instructions for generating sets in the power stations to be started up or shut down to meet at the lowest possible overall cost the ever-changing load pattern as it varies hour by hour, and sometimes almost minute by minute with the vagaries of the British climate!

The Standardized System

The three telephone manufacturing firms who had equipped the grid control areas at the outset and were therefore well versed in the development of grid control equipment—Automatic Telephone and Electric Co Ltd, The General Electric Co Ltd, and Standard Telephones and Cables Ltd—were invited to cooperate with the then British Electricity Authority in the design and production of a 'standardized system', as it came to be called. This approach resulted in an agreement which (*a*) permitted the free interchange and use of technical information between the manufacturers, (*b*) ensured the further development of the system for the duration of the agreement, and (*c*) safeguarded the system against arbitrary alterations.

The Authority and the telephone manufacturers concerned set up a Telecommunications Technical Committee (TTC) to be responsible for the design of the standardized system, for the development of the system to suit changing requirements and to keep in step with competitive developments.

It became evident in view of the complex variety of stations and network conditions, that the standardized system could not be a precise installation with universal application, but would instead be the rigid standardization of many different items of equipment which would be installed in different combinations to suit the requirements of different stations.

The standardized system was designed to use ordinary-grade Post Office lines with

(*a*) Earth-return phantom dc signals for the infrequent traffic of general indications, visual instructions, and telephone calls. On lines where dc signalling could not be used, 300 c/s was used instead with 400 c/s high-pass speech filters;
(*b*) Above-speech vf signalling for high-density telemetering traffic using time-division multiplex 50-band transmission for 10 continuous readings on a single 120 c/s bandwidth channel.

The Authority (now the Central Electricity Generating Board) generally employs lines rented from the Post Office for the grid control networks because, with the complex power-system configurations and the large numbers of stations in the control areas, there is no practical alternative. From their very nature, rented telephone lines cannot be as reliable or as free from accidental interference as pilot cables, but their use for grid control purposes during the last twenty-five years has been very satisfactory.

Communication Networks for Grid Control Areas

In the network planning of the standardized system the outstations in a grid control area are defined as either major stations or minor stations. A major station is usually a generating station with or without a grid station, or a large attended grid station not associated with a generating station. Only major stations can send signals to, or receive signals from, a GCC. A major station usually has a direct line to the GCC, in which case it is termed a radial station, and has also a direct line to each minor station associated with it, usually not more than three or four. A minor station is usually a small grid switching and transforming station or a bulk supply point to an Area Board. A minor station can only send signals to, or receive signals from, a major station.

To economize in rented circuits the more distant major stations can be connected in groups usually of 2, but up to a maximum of 4, stations. A group is served by a common line from the GCC to the nearest or most important station in the group, and from this parent station (as it is called) by separate lines to each of the other stations in the group, which are known as satellite stations.

For their mutual reinforcement, pairs of major stations served by separate lines to the GCC are interconnected by tie lines. These lines provide an alternative although indirect means of communication between the GCC and the major stations, together with their minor stations. The more important radial stations may be provided with second lines to the GCC, switched to take over service on instruction from the GCC over the reserve line should the normal line fail. In normal use, reserve lines operate as inter-PAX tie lines between the GCC and the stations. Tie lines and reserve lines are routed by the Post Office to avoid cables containing grid control lines.

Groups of stations in a Division without a GCC are usually connected by local lines to the telephone board at the Divisional Headquarters, where the operator extends calls between the stations and the Divisional Headquarters PAX telephones. This arrangement confines the administration traffic within the Division and increases the usefulness of tie lines, parent-satellite lines, and major-minor lines which group the stations for grid control purposes. Grid control traffic takes priority over inter-station and Divisional traffic.

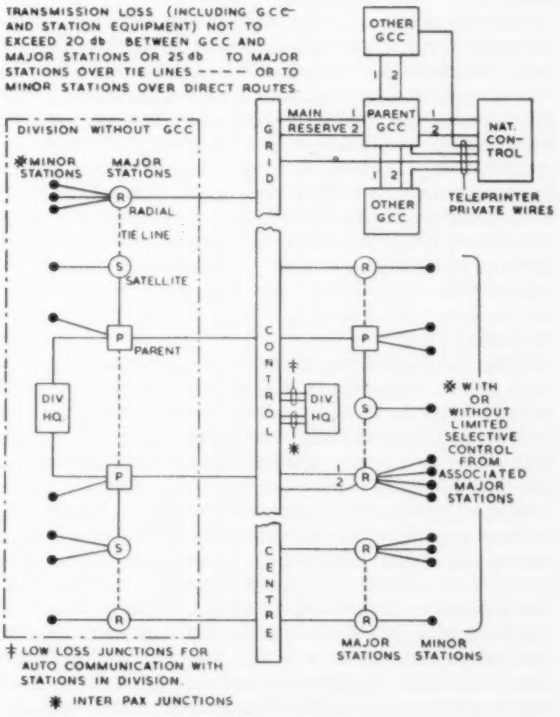
In Divisions with a GCC, inter-PAX tie lines are provided between the Divisional Headquarters and the GCC. Low-loss 4-wire junctions are also provided so that the Divisional Headquarters PAX telephones can dial into the standardized system at the GCC to initiate calls to any outstation control telephone or to any power station telephone operator in the Division. Calls to the Divisional Headquarters from the outstations are received at the GCC and relayed over these junctions to a cordless telephone board at the Divisional Headquarters, where the telephone operator extends the calls into the local PAX. This Divisional traffic does not require the services of the telephone operator at the GCC, and although it makes use of the control apparatus and the grid control network, it does so on a non-priority basis so as not to inconvenience grid control traffic.

Standard Facilities in Grid Control Centres

In each of the new grid control rooms there is

(*a*) A mosaic switching diagram.
(*b*) A feeder flow diagram.
(*c*) A miscellaneous instrument and recorder suite.
(*d*) A switching desk, or desk.
(*e*) A loading desk.
(*f*) A clerk's desk.

Based on their satisfactory performance over the past twenty years, mosaic switching diagrams are used to display


TRANSMISSION LOSS (INCLUDING GCC AND STATION EQUIPMENT) NOT TO EXCEED 20 db BETWEEN GCC AND MAJOR STATIONS OR 25 db TO MAJOR STATIONS OVER TIE LINES – – – – OR TO MINOR STATIONS OVER DIRECT ROUTES.
OTHER GCC
MAIN
RESERVE 2
PARENT GCC
NAT. CONTROL
OTHER GCC
TELEPRINTER PRIVATE WIRES
DIVISION WITHOUT GCC
*MINOR STATIONS
MAJOR STATIONS
RADIAL
TIE LINE
SATELLITE
PARENT
DIV HQ
DIV HQ
GRID
CONTROL
CENTRE
* WITH OR WITHOUT LIMITED SELECTIVE CONTROL FROM ASSOCIATED MAJOR STATIONS
‡ LOW LOSS JUNCTIONS FOR AUTO COMMUNICATION WITH STATIONS IN DIVISION.
* INTER PAX JUNCTIONS
MAJOR STATIONS
MINOR STATIONS

Typical communication network for a Grid Control area

in detail in schematic form the grid system and generating stations of the control area. A mosaic diagram comprises many thousands of 1-in plastic squares of a pastel shade; most are blank but some are engraved to portray circuit-breakers, isolators, earthing switches, generators, transformers, reactors and sections of line or busbar, and coloured to represent the appropriate system voltage. By replacing blanks with symbols it is a simple operation to keep the diagram in step with system development. For a typical control area comprising 20 generating stations and 30 grid transmission stations, the average 1-in mosaic switching diagram is about 50 ft (15 m) long by 9 ft (2·7 m) high with 1500 semaphores for circuit-breakers, isolators, and earthing switches. Usually about 500 automatic indications are provided.

Feeder-Flow Diagram

An animated feeder-flow diagram was first used at National Control in 1937. The usual flow diagram is a straight-line schematic on a pastel background showing the area transmission system with the lines coloured to represent the appropriate system voltages. At each station on the diagram, represented by small circles or rectangles, each line has a green 'line-end-open' lamp which lights automatically whenever the corresponding grid line is open-circuited by the station switchgear. Telemeters positioned in the mimic power lines indicate the magnitude and direction of active and reactive power flow in the various 275 kV power lines and transformers and in the majority of the 132 kV lines. A typical feeder-flow diagram has about 100 telemeters and is 25 ft (7·6 m) long by 9 ft (2·7 m) high, constructed of 6-in plastic or 20-in steel square tiles. Most mimic power lines on the diagram have a red lamp which flashes whenever the current in the corresponding grid line exceeds a preset value between 80 and 160 per cent of normal full load.

The miscellaneous instrument and recorder suite, which is sometimes a continuation of the feeder-flow diagram, accommodates continuous-balance 10-in strip-chart MVAr indicator-recorders of area net transfer and area total generation. Small 3-in strip-chart recorders are provided for each 275 kV inter-area-feeder MW telemeter, and also for switching into regional system-frequency or system-voltage telemeters and for connecting into individual feeder-flow or station total-generation telemeters. In some of the GCC's a 3-in recorder is used to record the passage of lightning storms as detected by special radio equipment.

Switching Desk

Facing the switching diagram is a control desk for each of the two switching engineers. On a wing of the switching desk is a keyboard console on which the switching engineer can selectively call any control telephone in the area and answer any kind of call from the network.

The keyboard consoles have check keys for each major station to enable the control engineers after equipment outage to bring back signal trains from the various stations to confirm the circuit-breaker indications and the directions of flow indicated by the telemeters on the feeder-flow diagram. On one keyboard console there is a remote control panel for a 12 kW standby diesel-driven alternator with a voltmeter indicating the Area Board mains supply to the GCC. The voltmeter has a segment of the scale coloured green to remind the control engineer of the voltage limits beyond which he must change over the control-centre apparatus to the standby alternator. During mains failure and until the diesel is on load, lamps energized from the 50-volt battery light automatically in the control room to enable the control engineers to operate the diesel control panel (similar facilities are provided in the apparatus room and diesel house). A 'mains volts' alarm is displayed on the central annunciator during mains failure or low mains voltage. There is a similar control panel on the other switching desk for a 25 kW diesel-driven alternator which supplies the domestic needs of the establishment during mains failure and also serves as standby to the GCC apparatus during overhaul of the 12 kW set. The domestic diesel set is installed in the office block and is arranged for automatic starting and load change-over.

Loading Desk

The loading desk in front of the feeder-flow diagram usually has accommodation for two loading engineers. Each engineer has a logging clock, three telephones, and a keyboard console similar to those used by the switching engineers. In the desk facing the loading engineers are 10-in indicator recorders for area net transfer, area total generation, and system frequency. Associated with the recorders are instruments indicating positive and negative rate of change of system frequency, and daylight intensity (as telemetered from the main industrial load centre of the control area). There is also a continuous indication of system frequency from an amplified system-frequency-modulated vf signal transmitted from a grid station. At any time, the loading engineers can use the amplified signal instead of the local mains to energize the system-frequency instruments, a change which is automatically made in the event of mains failure.

On the loading desk is a 16-way message instructor on which the loading engineer can set up any of sixteen stereotyped instructions for broadcasting to any number of attended stations, and observe individual station acknowledgments.

On a console adjacent to or combined with the loading desk are the individual station-generation instructors and telemeters (megawatts 'sent out', megavars 'gross'). The instructor is a manually adjusted pointer superimposed on the megawatt telemeter scale and geared to a transmitter coding mechanism.

At generating stations, in addition to direct-wire operational telephone systems between key points, PAX telephones are provided for general internal communication.

Control telephones at minor stations operate as party-line extensions on the associated major station's control telephone system. Push-button calling is provided between the party telephones, with indicators to inform the would-be user when the other party is using the line.

Generation and Visual Instructors

On the control desk in the power stations there are a control telephone and local telemeter indications similar to those telemetered to the GCC of the station's total generation in megawatts 'sent out' and megavars 'gross'. In addition, there is a 270 deg-scale indicator which responds to the GCC loading engineer's generation instructions, with a lamp and an alarm to announce the receipt of each fresh instruction.

Control room of the North Thames Grid Control Centre showing the switching diagram on the left and the feeder-flow diagram on the right

Also on the control desk are 16 combined lamps and twist buttons for the display and acceptance of visual instructions transmitted by the GCC loading engineer and a button to re-light the last instruction received.

Unless remotely controlled by the Area Board concerned, unattended minor stations are controlled over the grid control network by the Generating Board from the associated major stations, which are usually generating stations and therefore attended. Automatic 2-stage load-shedding equipment can be provided at unattended stations to take effect under fault conditions when generating stations are grossly overloaded and frequency is low.

Delayed Automatic Reclosing Equipment

This description of grid control facilities would be incomplete without some reference to equipment now being provided by the Generating Board at unattended outstations for the delayed automatic reclosing of grid circuit-breakers after power-line faults or faulty transformers have been automatically isolated from the transmission system.

It can be provided at all types of station, but so far has been installed only at single- and 3-switch 132 kV grid stations subject to loss of limited selective control due to failure of rented lines. Allowing time for oil recovery in the arc-control devices of the oldest types of grid circuit-breaker, the 132 kV section switch at the unattended station recloses 15 sec after a grid line fault to re-energize the line, but only if the line has remained de-energized during that period. On instruction from the GCC the line is then closed at the attended station after system synchronism has been checked. Fifteen seconds after the successful reclosure of the section switch the transformer switch recloses. Switches which trip when being reclosed, or during the next 2 sec, are locked out automatically and prevented from further reclosing. During a shut-down caused by a double-circuit line fault the section switch will reclose 15 sec after either of the power lines has been successfully re-energized from the other end, and in the event of a sustained line fault the line isolator can be arranged to open automatically after an unsuccessful section switch reclosure; the transformer is then put back on load by reclosing the transformer and section switches.

At single-switch 132 kV stations a fault on one of the grid transformers trips the grid section switch and low-voltage transformer circuit-breaker and then trips the remote 132 kV line circuit-breaker by means of a 132 kV fault thrower or by intertripping over a rented line. The transformer isolator then opens automatically, and 15 sec later the grid section switch recloses to re-energize the line. A recent development automatically substitutes a spare transformer common to the station for the faulty one before reclosing the section switch.

Where two unattended stations with automatic reclosing equipment are in tandem on the same 132 kV system, the section switch at one station is arranged for dead-line charging, but the other section switch will only reclose after the affected power line has been successfully re-energized either from the dead-line charging station

or from the attended station, as the case may be, and then only when both lines are alive and the systems are in synchronism.

Although some time must elapse before the new National Control network is completed, the CEGB reports that operational experience has been most gratifying in those control areas where the standardized system has been in operation for several months.

The seven grid control centres, with the principal generating and switching stations under their control, and the manufacturers responsible in each case for the installation of the standardized system, are:

GCC	Major Stations	Minor Stations	Switching Stations, etc	Main Contractor
Newcastle	15	11	19	Standard Telephones & Cables Ltd
Manchester	29	19	31	Automatic Telephone & Electric Co Ltd
Leeds	22	16	15	Standard Telephones & Cables Ltd
Birmingham	28	26	36	General Electric Co Ltd
Thames North	21	22	17	Standard Telephones & Cables Ltd
Thames South	23	8	23	Automatic Telephone & Electric Co Ltd
Bristol	31	35	37	Automatic Telephone & Electric Co Ltd

A full description of the system is given in the following two papers to be published in the Proceedings of the Institution of Electrical Engineers, Volume 105, 1958, Part A: '*The Development of Communication, Indication and Telemetering Equipment for the British Grid*' by G. A. Burns, F. Fletcher, MBE, C. H. Chambers, and P. F. Gunning, and '*Standardization of Control Facilities for the British Grid*' by P. F. Gunning.

The Windscale Incident

With the publication of the final Report of Sir Alexander Fleck's Committee* appointed to investigate the Windscale incident of last October, it is now possible to view this event in perspective.

It will be recalled that the initial cause of the accident in the Windscale No 1 reactor was the release of Wigner energy from the graphite, and it is relevant to note that, although the phenomenon of Wigner energy has been known for some time, such knowledge was extremely limited when the Windscale piles were designed over ten years ago, and that such energy could be released spontaneously or by controlled annealing was not clear. Theoretical and experimental studies of Wigner energy and its release have now been made for a number of years and a great deal of additional knowledge has been accumulated.

The Windscale incident was a spectacular piece of news when it happened—and the non-technical press naturally tended to make headlines out of it for several weeks. But, as Sir Christopher Hinton emphasized in his paper to the BEPC, the incident taken in the perspective in which accidents are normally judged was a minor one.

It is also important in this context that Windscale was built to produce plutonium, and when its reactors were designed there was insufficient knowledge to permit the heat generated in the fission process to be usefully applied. Consequently the heat is removed by air blast through the reactors and dissipated to the atmosphere from the 405-ft (123-m) high chimneys, which are equipped with a filter gallery containing replaceable glass-wool filters capable of removing virtually the whole of any solid material which may find its way into the air stream.

Herein lie the essential differences between Windscale and Calder Hall and its successors. The latter were designed to utilize the heat generated by the fission process, and carbon dioxide is therefore used to cool the reactors and transfer the heat to the heat exchangers where steam is generated for the turbines.

Another major factor is that the stored energy accumulates at a rate which decreases considerably as the temperature during irradiation is increased. It is known that the amount stored from irradiation at 250 deg C is small, and that virtually no energy is stored at temperatures above 400 deg C. Coupling this with Sir John Cockcroft's statement that the fuel elements in the Calder Hall reactors operate at a surface temperature of 408 deg C, and Sir Christopher Hinton's statement that the maximum temperature in more recent designs is around 450 deg C, it will be appreciated that there is sure ground for asserting that Wigner energy is not a hazard in any of the commercial nuclear power stations.

Yet another important factor is that the carbon dioxide coolant in the Calder type of reactor is contained in a closed circuit, so that even if a fuel cartridge failed and caused a release of fission products into the coolant, the amount that could escape into the atmosphere from any leakages in the closed circuit would be too small to constitute any hazard.

These facts deserve to be widely known, since they are the foundation for the often-reiterated assertion that the British type of commercial nuclear power reactors are inherently safe.

* Cmnd 471, July 1958. HM Stationery Office, 1s.

New equipment and processes

New Ring Main Unit

A new unit (Type NX) designed specifically for tapping a ring main has recently been introduced by *Johnson & Phillips Ltd.* It comprises a standard J & P metalclad oil circuit-breaker with two wing oil switches assembled in one common structure, making a very compact unit measuring 6 ft (183 cm) high, 3 ft 9 in (114 cm) wide, and 4 ft 4 in (132 cm) deep.

A special feature is the design of the oil switches, which have manual spring-operated mechanisms which, after the initial 45 degrees or so of movement of the switch handle, take the action of the switch out of the operator's hands and give a uniformly rapid and positive opening and closing, irrespective of the speed at which the handle is operated.

The unit has a normal current rating of 400 A, with the oil switches rated at 250 MVA at 11 kV. Control of the tee-off circuit is by either a plain-break or an arc-controlled oil circuit-breaker, according to service requirements, the breaking capacity ratings being 150 MVA at 6·6 or 11 kV (plain break), or 250 MVA at 11 kV (arc control).

Provision is made for inserting cable testing plugs, or an alternative arrangement of built-in test terminals can be supplied, if required. In either case, a foolproof and complete system of interlocks is incorporated.

The oil switch sections have been tested and certified to BS 2631 and the circuit-breakers are certified to BS 116.

The Creda 'Mercury' Cooker

Advance information has been released to the trade of the new Creda 'Mercury' cooker which will be put on the market next month.

It incorporates several departures from conventional design, of which the most noteworthy is perhaps the care and attention which have been given to the hob to ensure speed, flexibility of control, easy wipe-over cleaning, and comfortable working conditions. The result is an entirely new type of boiling unit and hob construction.

To begin with, the hob height has been made 33 in (86 cm) high instead of the normally accepted 36 in (91 cm); this makes the handling of pans and so on easier and more comfortable.

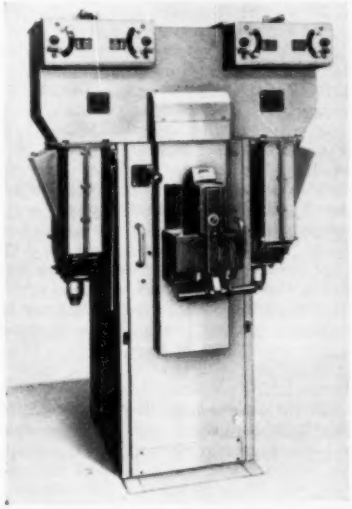
Next, the boiling rings—to which the name of Creda 'Quick-discs' has been given—represent a new approach to boiling-ring design. All the three rings are circular and of the same size—just over 7 in (180 mm) in diameter. The top casting, of a special rust-resistant iron alloy, is thin and light and therefore quick to heat up and quick to respond to changes of control setting. A stainless steel bezel pressed on to the rim of the casting forms a spillage-proof seal; the ring rests on a circular ridge raised in the dished portion of the hob, so that any spillage is prevented either from reaching the element or running on the floor.

The control system is novel in that, on first switching on to 'full', the regulator contacts remain closed for about 45 seconds to give quick heating and then settle down to the normal cycle for an average loading. The 'Quick-discs' themselves are made with a very high loading—much greater than they could withstand in continuous operation. In the case of the fastest disc, there is an additional control unit which makes the regulator inoperative for about 3 minutes to provide a still more powerful boost. This regulator system also compensates for mains voltage fluctuations and enables the range from 200 to 250 V to be covered by two voltage ranges instead of four.

Other notable features are a newly designed large size grill located in a recess in the roof of the oven; large warming drawer controlled by its own switch; all controls in a convenient but safe position on the top of the back splash plate; 'domes of silence' fitted to the base so that the cooker can easily be moved for cleaning behind and beneath it. Colours are white or cream, with polished stainless metal trim.

The 'Mercury de Luxe' has the additional features of an oven timer which also controls the warming drawer; glass inner door to the oven, and automatic oven interior light.

Both models are competitively priced, and their special features should commend them strongly to the export markets.

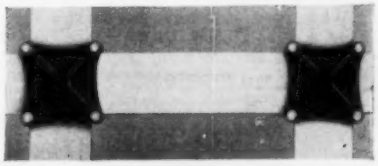


Ring main unit by Johnson & Phillips Ltd

Ferranti Busbar Clamps

A series of flat busbar clamps is available from the Foundry Department of *Ferranti Ltd*, Hollinwood, Lancs, which should provide a useful service in that they are ready for immediate assembly and need no machining or finishing operations.

They are cast in Ferranti 'NOduMAG'—a non-magnetic, high-strength ductile material, and are shell-moulded to give a good finish and dimensional accuracy, with the bolt holes cored. They are supplied with the clamping surface ground, and are given a protective coating of damp-resisting varnish. Physical properties are quoted as: tensile strength, 24-28 tons/sq in (38-44 kg/sq mm); yield point, 18-22 tons/sq in (28-35 kg/sq mm); elongation, 8-12 per cent. Standard flat busbar sizes are 2, 3, 4, 6, and 8 in (5, 7·6, 10·1, 15·2 and 20·3 cm); intermediate or larger sizes are available on request.



Ferranti busbar clamps

English Electric Vee-line hot-plates

Called 'Vee-line' because of the distinctive shape of the element—an inverted triangle—these new *English Electric* hot-plates are claimed to give maximum area of contact with the cooking utensils, thereby increasing heat transference. The plate is connected to the terminal box by a patented swivel mount which allows it to be lifted clear of the support and spillage tray, making for easy cleaning of both plate and reflector.

The element is a double spiral of nickel-chromium alloy embedded in magnesium oxide and Inconel sheathed. The reflector is a deep pressing of heavy gauge polished aluminium which allows spillage to drain away clear of the elements. The terminal box is vitreous enamelled and has plug pins to fit the standard EDA sockets for single and double circuit connexion.

The Vee-line plates are available in 8 in (203 mm) and 6¼ in (159 mm) diameter, with loadings of 2100 W and 1250 W respectively, in voltage ranges of 200/210, 220, 230/240, and 250.

GEC Small Induction Motors

A new range of small single-phase 50 cycle induction motors from 1/40 hp to 1/10 hp and continuously rated to BS: 170/1939 is announced by *The General Electric Co Ltd.* Rolled steel shells with pressed-in wound stator cores form the motor bodies, with aluminium pressure-cast bearing brackets spigoted into each end. Sleeve bearings, diamond bored true with the bracket spigot, are fitted as standard, and oil saturated felts provide lubrication for prolonged running without re-oiling. The squirrel-cage rotors, cast in aluminium, are dynamically balanced and fitted with an accurately ground high-grade steel shaft. All motors are electrically reversible, and an arrangement of thrust washers at the opposite driving end bearing permits the motors to be run in any position.

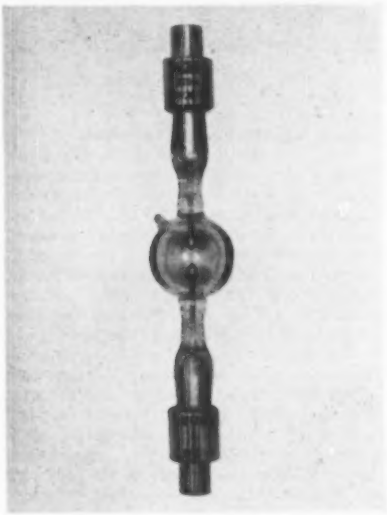
The motors are available either as capacitor start-and-run or split phase. It is stated that the capacitor start motors develop moderate starting torque, have good overload capacity, and are particularly suitable when starting conditions may be prolonged. They are provided with

continuously rated impregnated paper capacitors in welded oval aluminium cans for separate mounting. The split phase motors are supplied with separately mounted current-operated relays in moulded cases.

Two new Siemens Lamps

Illustrated here is the new 1000 W high pressure mercury/xenon lamp by *Siemens Edison Swan Ltd*. It combines high efficiency with a peak arc luminance of 20,000 stilbs, enabling it to be used for special applications—such as in flight control equipment—as well as for normal black and white projection purposes.

When used with approved Siemens Ediswan control gear, a shorter run-up period is obtained and the lamp may be switched on and off even when it is still hot.



Siemens Edison Swan Ltd's new 1000 W high pressure mercury/xenon lamp

Another notable development is a new miniature projector lamp known as the A1/176, which is the first lamp of its kind to be produced commercially containing a 500 W (200/250 V) biplane filament in a 25 mm soft glass bulb. It has been specially developed for use in small slide projectors and has an efficiency of 24 lumens/watt.

Electrical Tachometers

Basically the electrical tachometer consists of a transmitter or generator and a separate indicator, the generator being so designed that it provides a voltage proportional to the speed of rotation over its entire speed range, and the indicator comprises a voltmeter calibrated in revolutions per minute, feet per second, or any other function.

Crompton Parkinson Ltd have developed new types for particular applications. One is a portable indicator designed for experimental use in technical colleges; it has an 11-inch (279-mm) 240-degree scale and is contained in a black plastic case approximately $8'' \times 8'' \times 4\frac{1}{2}''$ ($203 \times 203 \times 114$ mm). In its most popular form, it is fitted with a duplicate set of terminals allowing selection of ranges of 0-1500 or 0-3000 rpm.

The other is a short range speed indicator —a development made possible by the fact that the Crompton Parkinson transmitter generates an alternating current. Since the frequency and voltage vary in a linear relationship with speed, it is possible by inserting a frequency sensitive network between generator and indicator to provide a scale which covers only a selected narrow range of speeds.

The 3-phase output from the tacho generator is divided into two circuits per phase. One circuit of each phase contains an inductor and in this way a substantially constant reference voltage is obtained at any speed covered by the range of the instrument. The other circuit of each phase passes through a resistor and provides a current proportional to the absolute speed.

Each of the two circuits is fed into a 3-phase full wave rectifier; the two dc outputs from the rectifiers are applied in series to the indicator, which measures the difference between them.

The short-range scale on this type of indicator facilitates very fine speed control. For example, on a 6-in dial instrument, the pointer tip moves nearly 1/16 in (1·6 mm) for every 1 rpm variation. The combined accuracy of generator and indicator, when calibrated together, is stated to be within $\pm 0{\cdot}5$ per cent of full-scale value.

300 Mc/s Voltmeter

Latest addition to the range of voltmeters produced by *Marconi Instruments Ltd*, St Albans, Herts, is the Type TF 1300 vacuum tube voltmeter—a low-priced instrument which is stated to be sturdy in construction and possessing good accuracy and stability.

On ac the measurement range is from 0·1 to 100 V at frequencies from 20 to 300 Mc/s; on dc the voltage range is up to 300, and the resistance range up to 4 MΩ.

The indicating meter is direct-reading on ac, dc, and ohms ranges, and no correction factors are necessary. Zero stability is of a high order with respect to both time and mains variation, and only one zero setting is required for all ac or dc ranges. Both ac and dc inputs are isolated from chassis.

Ac measurements are made with a lightweight cylindrical probe which allows direct contact with the circuit under test. The probe is small, compact, and fitted with a non-slip pvc sheath and safety guard, and is therefore very suitable for use in confined spaces. The rectified output from the probe is applied to one arm of a valve bridge comprising two double triodes; a second arm of the bridge is coupled to a splash-current balancing network including a potential divider across the ht supply and a 3-volt stabilizer element. The indicating meter is automatically protected from overload.

For dc measurement, the input is applied directly to the bridge, and the probe diode and splash-current network are automatically disconnected. For resistance measurement, the unknown resistor is connected in series with a standard resistor and the 3-volt stabilized supply. The meter responds to the voltage developed across the unknown resistor.

New BTH products

Among the new equipment announced by the *British Thomson-Houston Co Ltd*, Rugby, Staffs, in recent months is a vertical high frequency motor-alternator set, and a new isolating switch for their type DOC 71 contactor starter.

The first-named is a medium rating (75-300 kW) high-frequency generating equipment for induction heating and melting applications at a frequency of 8·7 kc/s. As it is arranged for vertical operation, it occupies far less space than a normal horizontal machine of the same rating; it is claimed to be very quiet in operation.

The first set in the range has an output of 75 kW. It comprises a heteropolar inductor alternator and a squirrel-cage induction motor, the motor being mounted vertically above the alternator. The frame and the shaft are mounted on the bottom end-shield and the set is supported on four resilient mountings. The set is totally enclosed inside sheet metal covers (which can be easily removed), and is cooled by two water coolers, one being placed in the alternator stator core and the other wound spirally round the motor frame.

BTH can also offer a similar vertical set of a higher rating, and sets will shortly be available for operation at 3 kc/s and 8·7 kc/s with approximately double the output of the present machine. Under suitable conditions, these alternators may be operated in parallel to supply higher powers than can be generated by a single unit.

The second item extends up to 5 hp the established range of type DOC 71 starters for single- or three-phase motor starting, and makes it possible to offer a range fitted with 3- or 5-pole isolating switch units. An ammeter box and a HRC fuse-box are also available for fitting to the switch assembly.

BTH vertical HF motor-alternator set

The switch can be supplied as a 3-pole 'on load' version rated at 30 A maximum (tested to break 100 A at 440 V) or alternatively in 5-pole form with three main 30 A poles and two normally-open auxiliary poles for control circuits.

These new starters comply in every respect with BS 587: 1957 for 'frequent-duty' starting (*i.e.* 40 starts per hour).

The 1958 CIGRE Conference

A Commentary by J. H. M. Sykes, Assoc IEE

Now that the 17th CIGRE Conference can be looked at in retrospect, the trends at this international gathering of electrical engineers concerned with power transmission begin to appear rather more clearly than they did at the time in Paris, when all the 1800 members present were deeply immersed in a sea of facts and figures emerging from 140 papers and 14 sessions of discussion, with the addition of Study Committee meetings for many of the members from Britain.

There was a full attendance of delegates from Great Britain, including very many from BEAMA member-firms. Ten of the papers were either entirely of British origin or had a predominance of British authors.

It might have been thought that the onset of nuclear power generation, even though still a matter of paper planning in so many countries, could have begun to change the viewpoint of some engineers as to the future need for large-scale power transmission over long distances. It was very soon after the opening of what is regarded by many as the most important session of the whole conference—that dealing with extra high voltage power transmission in general—that this potential bogey was brought out into the daylight and summarily despatched.

Mr Philip Sporn, who presided over this session and had flown from America especially for this single day's discussion, said straight away that many present had seen the load double in ten years three times over; and this doubling, which showed no sign of abatement, was the driving force behind extra high voltage power transmission designs. The loads and the demands, he said, are 'way beyond what we had thought they might be'.

Mr Sporn said that extra high voltage power transmission development is not nowadays the prerogative of a few countries. Technology in this field is vigorous and expanding. He thought that the CIGRE Conference had the great advantage of providing international cooperation at minimum cost and effort.

High Voltage Transmission

In the section on extra high voltage power development, the Special Reporter was M. François Cahen of Electricité de France. M. Cahen will be specially remembered by readers of THE BEAMA JOURNAL for the lectures delivered at London University in March 1951 and published in this Journal later in that year.* These lectures gave a brilliant survey of the problems of power transmission at voltages above 225 kV.

What is the situation now, seven years afterwards? A report by Mr Sporn to the session, outlining the activity of the CIGRE Study Committee on this subject, summarized the present position. It showed that in France the conversion of a 275-mile (440-km) double circuit 225 kV line to a single circuit 400 kV line was completed late in 1957, and is now in operation. A total of 775 miles (1247 km) of convertible construction is planned or is now in operation at 225 kV, and will be converted to 400 kV in the future; and a total of 1790 miles (2880 km) of line is either in existence, being built, or planned for ultimate operation at 400 kV. CIGRE delegates had the opportunity of inspecting at the Plessis-Gassot substation the Paris end of the first French 380 kV line.

A World-wide Trend

In Sweden a line operating at 380 kV was put into service in 1956, and by the end of 1958 it is expected that some 1910 miles (3070 km) of 380 kV lines will be in operation. In Western Germany 210 miles (338 km) of 380 kV line, having the unusual feature of employing four conductors per phase, were made alive in 1957. In the USSR the voltage of 400 kV was first used in 1956, when a total of 1060 miles (1705 km) of line at this voltage were made alive. An additional 2000 miles (3220 km) of line is now under construction, and it is expected that by 1960 a total of 3100 miles (4990 km) of 400 kV lines will be in operation. In that country (as will be mentioned later) it has been found possible to convert the original 400 kV lines to 500 kV.

In Finland 240 miles (386 km) of line designed for 380 kV, and now running at 220 kV, have been put into service, and additions are contemplated, so that by 1960 it is expected that there will be 575 miles (925 km) of 380 kV line in service at the full voltage.

In the United States and Canada the voltage of 345 kV has been chosen, and in the USA there is now a total of 1520 miles (2446 km) in operation or being constructed for operation in the near future. Operating voltages up to 360 kV are now in use. In Canada several hundred miles of 345 kV lines are in service.

The 330 kV voltage level was mentioned by Mr Sporn in his review as relating only to Australia, where an extensive 330 kV system is under construction; and unaccountably there was no mention of the Kariba transmission project—among the largest in the world—which is also to be operated at the 330 kV level.

Great Britain and Japan share a predilection for 275 kV, and in October of last year the reports stated that 612 miles (967 km) of 275 kV circuits were in commission in Great Britain and 350 miles (563 km) in Japan.

The Special Reporter directed the discussion on extra high voltage development into three main groups: first, the development of the utilization of extra high voltages; second, the question of internal overvoltages; and finally, the corona effect, including questions of radio interference.

Under the first heading there was included a report from Great Britain, by Messrs P. W. Cash and A. Chorlton, on aspects of main transmission system development in England and Wales. This report, and the discussion, indicated clearly that the advent of a major nuclear plant programme will not cause any diminution in the development of the British 275 kV transmission system. The

* THE BEAMA JOURNAL, **58**, Nos 171–4, Sept, Oct, Nov, Dec 1951.

capacity of these plants and their location, together with the influence of the increase of size of conventional coal-fired stations, will mean yet more interconnexion.

In Sweden, the addition of nuclear plant was also shown to have little bearing on the development of the 400 kV transmission system, and this subject was not touched on by delegates from other countries. Thus we may conclude that no one in the transmission field is unduly worried about the lack of need for bulk transmission equipment in the future because of a change in the method of generating power.

Overhead Lines an Intrusion?

The first speaker in the discussion was Mr F. J. Lane, formerly Deputy Chief Engineer (Transmission) of the Central Electricity Generating Board, and now a partner in a leading consulting firm. His interjection in the discussion was somewhat unexpected. He said that electrical engineers should not presume too far on the vital nature of the service they provide for the community. The overhead line, Mr Lane said, obtruded too much on society at present. Radio interference obtruded on society; the size of transmission line towers continued to increase. He was appalled by the appearance of some parts of the countryside, not only in England but in many other of the countries he had visited, with the cluster of transmission lines sometimes showing up on all sides of the horizon in the vicinity of major substations.

Mr Lane continued by indicating what steps might be taken to reduce this intrusion on society. First, maximum use might be made of the routes at present in use and the future routes which of necessity would be required. For example, double circuit lines were preferable, from this point of view, to single circuit lines. More attention should be paid to the limitation of internal overvoltages, so that the insulation of the lines could be employed to greater advantage. In regard to insulation, Mr Lane thought that the present cap and pin type of insulator was not necessarily the ultimate answer.

Although at present the cost of undergrounding a 275 kV overhead line in which the two circuits together carried 550 MVA was about sixteen times that of the overhead construction, Mr Lane felt that this ratio could be reduced. He emphasized the work that had been done on direct current cables. He concluded by saying that this problem of the ever-increasing number of overhead lines is around the corner for everyone in this field of engineering, and deserves urgent attention.

Mr Sporn, the Chairman of this session, intervened again to agree with Mr Lane that in settled communities there was already a very limited space for overhead lines, and this space was obviously decreasing. In the United States, there was a 'right of eminent domain', whereby a public utility could acquire compulsorily the right to build overhead lines, but he emphasized that these rights were used, and should be used, with the greatest possible discretion. He said that many people thought overhead power transmission towers were *ipso facto* ugly. Engineers, he said, should not pretend not to know anything about beauty. He advised them, when they left the conference room, to glance upwards at the Eiffel Tower and to realize that towers need not be a blot on the landscape. (However, an eminent British delegate whispered to your Correspondent that even Mr Sporn might change his mind if he saw a line of Eiffel Towers stalking away across the countryside; and this remark has considerable point when it is realized that some of the towers nowadays proposed for special duty such as river crossings are of the same order of height as the famous Parisian landmark.)

The Russian contribution to the discussion came from Mr Lebedev, who said that in the USSR it had been decided that a figure of internal overvoltage of 2·5 times the phase voltage could now be safely used, instead of 3 times the phase voltage, which was the figure taken into account in the original calculations for the 400 kV line. Largely because of the influence of this factor, they had decided that it would be practicable to convert the 400 kV lines to 500 kV working with 15 per cent increased capacity, and a programme directed towards this end was now in the course of execution. They found that the towers and all the substation equipment, excluding the transformers, could be converted relatively cheaply and simply. The first 500 kV line, now under construction, would form part of the complete grid system for the European area of the USSR.

In the Asiatic part of the USSR, Mr Lebedev said that their problems included the transfer of energy on the scale of 2000 MW for 2000 km. For bringing in the energy from hydro-electric plants there was obviously no alternative; but when it came to the exploitation of large coal and oil reserves, he said that they had to consider whether or not pipe-lines might not compete in regard to energy transmission.

They were considering whether to go up to 600 kV or even 700 kV ac for these transmission projects, and they had done a great deal of work on direct current power transmission operating at 800 kV or 1000 kV. The Stalingrad-Donbass dc project at 800 kV is about to start construction.

Single and Double Circuit Lines

Mr Lane's point about the multiplication of overhead lines was taken up by several speakers. Two eminent French engineers, for example, pointed out between them that the alternative to more transmission lines might well have been the inception of a greater number of power stations in urban areas, giving much greater pollution of the air. They also said that, although a single circuit line does not utilize the terrain to the maximum advantage, nevertheless each country has its own special problems. In France economic reasons had made them decide on the installation of 225 kV double circuit lines which later could be transformed into single circuit 380 kV routes.

An interesting Canadian paper described the change-over of a wood pole line from 115 kV to 230 kV, but Mr Casson, of the Central Electricity Generating Board, rather criticized this project in the sense that the original design must have been somewhat uneconomic, since only the addition of two extra insulator discs was required for this very considerable increase in voltage. He thought that, in line with Mr Lane's suggestions, the uprating of lines must receive proper consideration. On the other hand, he said that to convert a double circuit 132 kV line to a single circuit 275 kV line would double the power transmission rating, while to change a 275 kV line to a 380 kV line would only increase the transfer capacity by 50 per cent. He thought that, in spite of the problems of installing new overhead lines, it was better to reinforce a system by installing a new line unless it was possible to double the rating of an existing line. Mr Casson also referred to a paper from West Germany in which it was indicated that the earth wire conductor was the same

size as each of the phase conductors in the bundle. He thought this unusual specification was justified on the grounds of higher short-circuit strength, and he felt that, in general, a heavy current capacity in the earth wire reduced losses, since not inconsiderable currents flowed in the earth wire under normal conditions.

Reactive Power

Mr Lalander, of the Swedish State Power Board, raised the point of reducing the duties on future large-scale overhead line power transfer systems by avoiding the transport of reactive power. He thought it best to generate reactive power near to the point of consumption, rather than at the generating point. In general, he felt that shunt capacitors formed the best method of producing the reactive power, but in the large substations they preferred synchronous condensers. They had decided to employ units of 100 MVA.

In the discussion on this point, Mr Cash (CEGB) said that in Great Britain we also found that it would be desirable in the future not to transport reactive power, and we were proposing to use 40 MVA synchronous condensers, although none was actually installed at the moment. The requirement for reactive power would come gradually, Mr Cash said, and it will be distributed over a number of points.

From the USA there came news of a proposed experiment with a 750 kV project, and an experimental line section was to be built mainly in order to obtain experience in regard to radio interference.

Although both the Russian and American engineers mentioned voltage levels in the 700 kV region as being possible for future use, nevertheless it seemed to be a fairly widely held opinion that the economic advantages of increasing transmission voltages much above 500 kV were not as great as had been anticipated, and the curve of cost versus voltage began to level off. This point was made by Mr Lane, implied by Mr Casson, and stated by Swedish delegates, who said that although they had made close economic studies of a 650 kV voltage level for distances of the order of 1000 km, the advantages over the 500 kV level seemed too small to justify the higher voltages.

The second main section of this session related to overvoltages. In his summing-up of the papers, M. Cahen said that this question was particularly important since the internal overvoltage level of a system was, in practice, considered as determining the insulation of the lines and the equipment. At extra high voltages, he said, flashovers on line insulators due to atmospheric overvoltages were scarce, and automatic reclosing largely eliminated the effects of those overvoltages which did occur.

The Special Reporter drew attention to studies made in Sweden on this subject, which showed that for long transmission schemes the internal overvoltages likely to affect the lines near their ends are higher than those which may occur in the substations; and this may lead to an overinsulation of the lines in comparison with the substation equipment. Bearing in mind that insulation formed a major part of the cost of very high voltage lines, it was important that this factor should be taken into account. There was also the question of the favourable influence of a decrease of the system impedance or an increase in its short-circuit power at the connexion point of a long line, on the internal overvoltage level. The Swedish engineers had found that this influence was considerable and that as a system extended the overvoltage level increased, and the equipment insulation could in consequence be reduced.

Turning to the third main subject in this session—the question of corona and radio interference problems—it seemed apparent from all sides except one that radio interference was nowadays more important than corona loss. The exception was the Russian viewpoint, where it appeared that, although the Russian engineers thought it obviously desirable to reduce radio interference, nevertheless with their lines running largely over sparsely populated territory, the corona loss at 500 kV might well result in economic losses of no inconsiderable magnitude, whereas the radio problem was relatively unimportant.

The use of bundle conductors, with up to 4 conductors per phase (as at present used in Germany and to be used in the USSR), appeared to solve the corona loss problem as completely as would ever be possible.

With regard to radio interference, an American delegate said that this was one of the most complex problems in high voltage transmission, and the one about which there is still the most to learn. He felt that the approach in America would always be, if possible, to build a test line and then to analyse the results.

It was generally felt that there was no method yet evolved for pre-determining radio interference levels. The influence of altitude is obviously of importance, and American test results showed that at an altitude of 3000 metres the radio interference was 23 per cent higher than at 200 metres, the ratio of the air densities being approximately 1·35.

Apart from this session of the 1958 CIGRE Conference, perhaps the most interesting discussion emerged from the cable section; but before turning from overhead lines to underground cables, space may permit us to take the briefest of glances at the other sections.

Transport of Large Transformers

Many countries appear to have come up rather rapidly against the transport limitations of their respective rail and road systems on the movement of large transformers from the works to the site. We in Great Britain, in relation to rail transport, appear to be somewhat behind other countries in the maximum size of transformer we can handle, and a figure of 137 tons under the most favourable conditions was given for this country. On the other hand, it appeared that 200-ton transformers could be carried by road under exceptionally favourable conditions.

Discussion of this limitation naturally led to considerations of the transport of dismantled transformers; and here the question arose as to whether it was reasonable to expect, when a transformer had been carried to site in parts, that it was necessary for more than an overvoltage test to be called for. The general opinion appeared to be that impulse tests on site were too complicated and costly and could not, in general, be expected.

It seemed that there is a movement in most countries towards using 3-phase transformer units to a greater extent than before, up to a size of about 500 MVA.

A particularly interesting paper from Great Britain was presented by Messrs W. Casson and G. B. Harper of the CEGB, in which they compared the different types of transformer produced by British manufacturers for the British 275 kV system. The impressive total of 94 275 kV transformers ordered (up to September 1957), with 42 of these units either in service at that time or almost ready

for commissioning, showed the electrical world, in general, something of the achievements of our transformer industry; and since the survey was of an impartial nature, it was all the more valuable and will no doubt be widely read overseas.

An innovation in the transformer field was a proposal from a German source for the use of transductors in connexion with on-load tap-changing, to replace the series switches.

The Chairman of the transformer session, Mr E. T. Norris of Ferranti Ltd, drew attention to the lack of knowledge about the properties after service of the copper used in transformer windings, in relation to the behaviour of transformers under heavy short-circuits. He felt that this was a subject for considerable further research.

Cooling of Large Generators

In the generator section, the focal point of the discussion was, not unnaturally, that of improved methods of cooling for large machines, to enable the units now in design to conform to transport limitations (among other reasons). The paper by Mr W. Kilner, of Metropolitan-Vickers Electrical Co Ltd, on the practical experience gained with a 30 MW generator at the Bold power station* was heard with considerable interest, particularly in view of the complete success attending its commercial operation.

The question of cooling appeared still to be capable of several solutions. The most economical solution, as proposed in the discussions by several delegates, appeared to be rotors cooled by gas with stators cooled by a liquid which might be either oil or water. Nevertheless, it was agreed that each case needed careful study in relation to transport limitations and other dimensional problems.

The circuit-breaker section of this year's CIGRE Conference showed that the old familiar subjects are still evoking new points of view. For example, the study of post-arc currents is being pursued in a number of countries, but all that the Special Reporter could do in summing up the discussion was to say that it is hoped that the results which will be obtained will allow for a better knowledge of the phenomena which lie at the heart of the interruption of current in an arc. The second old favourite in the switchgear section is that relating to the problems of extrapolating results of synthetic tests on circuit-breakers, to enable their performance under full-scale faults to be forecast.

In this section, Messrs D. F. Amer and A. F. B. Young, of A. Reyrolle and Co Ltd, gave an authoritative opinion on this matter in relation to minimum oil circuit-breakers. As a result of an extensive series of tests at their company's new short-circuit testing station, they came to the conclusion that short-circuit tests on oil circuit-breakers or circuit-breaking units must be made at full current and full recovery voltage. They felt that tests at reduced voltage were inadequate for assigning ratings to such breakers, since the proper recovery voltage was essential for determining weaknesses in the electric strength in the proximity of the gas bubble, with consequent effects on arc re-ignition.

The general feeling that it had nowadays been possible to reduce the overvoltages which could be produced during the rupturing of small inductive or capacitative currents was welcomed by all the delegates interested in switchgear matters; but certain doubts were expressed, in the discussion, as to whether the low overvoltage figures were obtained by means which might possibly lead to a lessening of reliability.

Although the revised arrangements for CIGRE conferences are such as to permit certain subjects to be discussed only once every four years and direct current power transmission was not one of the subjects on the agenda for this year's meeting, nevertheless this relatively new method of carrying large blocks of power was significantly prominent in the cable discussions.

The Special Reporter of the cable section was Dr L. G. Brazier of British Insulated Callender's Cables Ltd, and he said in his special report that when the Study Committee on this subject last met, they decided that direct current cables formed the first preferential subject for the 1958 Conference. Five papers, including two from Great Britain, touched on this subject.

Within a very short period of time (as time is measured in relation to progress in power transmission), direct current has become accepted as the normal method for consideration in relation to any form of submarine cable exceeding a few miles in length. In fact, to quote from a paper by Messrs J. S. Møllerhøj of Denmark and C. T. W. Sutton and A. M. Morgan of Enfield Cables Ltd: 'The economic expansion of ac transmission schemes separated by water has, except in instances where the crossing is short and the voltage low, been impracticable both from the technical and economic aspects. The interest in the use of direct current transmission has been stimulated by the demonstration of its practicability by the successful launching of the Gotland scheme in Sweden, work in the USSR and Japan, and the issue of the enquiry for the cable to be used between England and France. At the same time, the relative merits of a dc scheme from all points of view have repeatedly been stressed in the past by CIGRE conferences and committee meetings. Consequent on these developments the cable engineer must now provide a submarine cable which will fulfil the requirements of a dc system.'

Submarine Cable Techniques

From the papers and discussions, it is obvious that there is still room for a good deal of argument as to the best form of cable for submarine work. One British firm, on the basis of experience gained on the very well-known Vancouver Island project, put forward strong claims for the advantage of continuous manufacture. This could be carried out with pre-impregnated paper cable under gas pressure or with solid type cable. On the other hand, many delegates expressed the view that it would, in any case, be necessary at some time to employ joints, since no submarine cable was likely to escape ships' anchors for ever, and thus flexible joints had to be developed, or at least some form of jointing technique for extra high voltage power cables would be needed.

Among the papers heard in this section was one from Messrs R. C. Mildner and E. D. Humphries of the Telegraph Construction and Maintenance Co Ltd, in which the authors said that plastic-insulated cables were now available for dc use, for voltages at least as high as 200 kV to earth. They urged consideration of the superior ageing properties of synthetic plastics because of their chemical inertness, and they stressed their uniformity and homogeneity when strictly controlled during manufacture.

The flat cable with fluid oil and special pressure com-

* THE BEAMA JOURNAL, **64**, No 1, Feb 1957.

pensating arrangements was the subject of a paper mentioned earlier from Enfield Cables, and as a result of considerable experience in Danish waters, coupled with the evolution of a two-core version for dc working, the authors felt that this cable had special claims for future submarine projects.

Mr E. L. Davey, of British Insulated Callender's Cables Ltd, said that for up to 100 fathoms (183 m) in depth the gas-filled cable was preferable, as it could be made for the highest voltages and could withstand the greatest water pressures, while for depths up to about 50 fathoms (91 m) he thought the solid type was preferable, and, moreover, it could be made in lengths up to 30 miles (48 km). It could be impregnated with compounds having setpoints well above the maximum working temperature, and consequently there would be no migration of compound and the cable would be elastic under all conditions. With regard to the plastic cable, which he felt was not yet fully developed for this purpose, Mr Davey thought that in the future it was clearly the only type of cable suitable for use at depths greater than 150 fathoms (274 m). In his view continuous manufacture for all types and all lengths of submarine cables was a vital necessity.

The delegates to the 1958 CIGRE Conference had the opportunity of making one or more of four technical visits: a modern French thermal station at Porcheville equipped with four 125 MW generating units; the regular visit to the Fontenay testing station of Electricité de France; an exhibition of electronic equipment used on the French National Railways; and an inspection of the 380 kV substation at Plessis-Gassot.

At this latter site, it was interesting to hear the comments of delegates on the 12,000 MVA suspended-type minimum oil circuit-breakers on the 380 kV system. It was amazing to compare these mentally with similar breakers of the bulk oil type. Those of us who had encountered high voltage switchgear maintenance problems wondered how long it would take to lower the breakers to the ground and re-suspend them. Nevertheless it was an extremely interesting arrangement.

* * * *

The real account of this CIGRE meeting—or, indeed, of any CIGRE meeting—could never be written; it would have to take account of the thousands of private conversations held between the engineers of every country, including many from behind the Iron Curtain, and the gradual revelation of differing or similar points of view on all the scores of basic matters concerned with long-distance power transmission in which every nation on the earth ultimately has a vital interest.

720 MW of New Generating Capacity

WITH the formal opening of two new power stations—Hams Hall 'C' in May and Tilbury in June—a further 720 MW of generating capacity have been added to the Central Electricity Generating Board's system.

Hams Hall 'C' is the third power station to be built on the Hams Estate; it is also the largest. The 'A' station, with a total plant capacity of 249 MW, was completed in 1938/39; the 'B' station was built during the war, and the final extension, giving a total output of 321 MW, was completed by the end of 1949. Hams Hall 'C', with a capacity of 360 MW, brings the total of the installed plant on the site to 930 MW and makes it the largest in the CEGB's system.

Situated some 9 miles (14·5 km) north-east of the centre of Birmingham, the site is bounded on its north side by the main Birmingham to Derby railway line, and on the south by a loop from this line which has a connexion into Leicestershire. To this loop are connected the whole of the railway sidings serving the three power stations.

The coal handling plant at Hams Hall 'C' is designed for a total capacity of 600 tons an hour direct from tipplers to bunkers. A coal store of 200,000 tons is provided, and the plant is designed so that in an emergency the station can be coaled wholly from store.

Each of the six boilers will generate 550,000 lb (249,500 kg) of steam per hour at 950 lb/sq in (66·8 kg/cm²) and 925 deg F (496 deg C) at the superheater outlet, with a feed water temperature of 385 deg F (196 deg C). The boilers are of the natural circulating water tube type, with water-cooled combustion chamber fired by pulverized fuel. They are designed to burn low-grade fuels, the design calorific value being 8200 BThU's per lb (gross) (4555 kg cal per kg).

The six 60 MW turbogenerators operate at a steam pressure of 900 lb/sq in (63 kg/cm²) and a temperature of 900 deg F (482 deg C) at the turbine stop valve, and run at 3000 rpm. The alternators, which are hydrogen cooled at a pressure of 0·5 lb/sq in (35 g/cm²) will give the full output of the turbine—60 MW—at 0·8 pf and at a voltage of 11,800. They are direct coupled to transformers stepping up to 132 kV, at which pressure they are switched on to the grid. The transformers, of the forced oil/air-blast type, are rated at 72,000 kVA and have on-load tap changing equipment to give a variation of ± 10 per cent nominal.

The arrangement of each turbine and boiler is on the unit principle, and there is no interconnexion on the steam or feed services.

Each unit—the turboalternator with its condenser and feed heating plant, together with its boiler and dust extraction plant—is controlled from a single control board situated at operating floor-level between the turbine and its boiler. In addition, each turbine has a supervisory panel situated near its governor end. This records the relative displacement of the turbine rotating and stationary blades, the eccentricity of the shaft, and other useful data on the behaviour of the machine.

Auxiliary Electrical Supplies

A 6000 kVA, 11·8/3·45 kV transformer is connected by links to each alternator to provide auxiliary supplies for

the associated turboalternator-boiler unit from a single busbar 3·3 kV switchboard.

Starting and standby supplies for the complete installation of six machines are obtained from two 10,000 kVA, 132/3·45 kV station transformers, which are connected to two duplicate busbar 3·3 kV switchboards. Interconnectors with synchronizing facilities are provided from this switchboard to the single busbar switchboards to enable the turbine and boiler auxiliaries to be energized from the station transformer switchboard until the alternator has been synchronized with the system, after which the auxiliary supplies are switched to the unit 6000 kVA transformer.

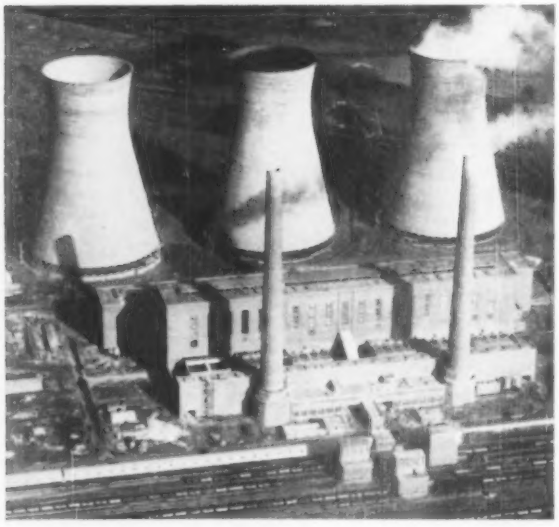
Common station services and the standby boiler feed pumps are connected to the duplicate busbar station transformer switchboard. Supplies to auxiliaries below 150 hp are at 415 V obtained through step-down transformers from the 3·3 kV system.

The 3·3 kV switchgear, of the metal-clad airbreak type with remote control features, has a rated breaking capacity of 150 MVA.

Main Switchgear and Transmission

With the commissioning of Hams Hall 'C', it was found desirable to reconstruct the 132 kV substation associated with the 'A' station, adding the necessary circuits for the 'C' station generators and outgoing feeders.

The new substation is of the outdoor type, with ferroconcrete structures carrying the busbars and isolators. It replaces the old substation and was built in a way which allowed the old lattice steel structure to be dismantled stage by stage, and the circuits to be progressively transferred to the new substation as the work proceeded, without prolonged outages of the circuits concerned.



Aerial view of Hams Hall 'C' Power Station looking north

The double busbars are arranged in four sections, with section switches and couplers. The reserve busbar is U-shaped with the main busbar inside it—an arrangement which allows connexions to be made to the front or back of the substation with equal ease and without resorting to high fly-over connexions; it also reduces the overall length of the substation.

There is provision for a total of 35 circuits: six generators, two station transformers, four grid transformers and four connexions to the adjoining 275 kV supergrid substation; the remainder are 132 kV feeders, bus section and bus coupler circuits, and three interconnectors to the existing Hams Hall 'B' substation.

Circuit-breakers are of the air-blast type of 3500 MVA breaking capacity and are remotely controlled from a central control room except the generator and station transformer circuit-breakers, which are controlled from the 'C' station control room.

The four grid transformers, with a total capacity of 195 MVA, are connected to the 11 kV busbars in the 'A' station and the 33 kV busbars in the 'B' station. Connexions to the 120 MVA, 275/132 kV supergrid transformers are by overhead lines.

Design and construction of Hams Hall 'C' was under the supervision of the Northern Group construction staff of the Midland Division (now part of the Midlands Project Group, CEGB), and the principal contractors and sub-contractors for the electrical equipment included:

Aiton & Co Ltd	*Evaporators and pipe-work*
Babcock & Wilcox Ltd	*Ash and dust handling plant*
British Insulated Callender's Cables Ltd	*Cables*
British Thomson-Houston Co Ltd	*Motors, auxiliary switchgear, and voltage transformers*
Thos. Bolton & Sons Ltd	*Rigid busbars and connexions*
Bryce Electric Construction Co Ltd	*Auxiliary transformers*
The Bushing Co Ltd	*Bushing insulators*
Chamberlain & Hookham Ltd	*Metering equipment*
Chloride Batteries Ltd	*Batteries*
Davidson & Co Ltd	*ID and FD fans, mechanical grit collectors, and booster fans*
Electric Construction Co Ltd	*Auxiliary transformers*
English Electric Co Ltd	*Reactors, motors, and switchboards*
Everett, Edgecumbe & Co Ltd	*Instruments*
Ferranti Ltd	*Transformers and rectifiers*
Foster Transformers Ltd	*Auxiliary transformers*
General Electric Co Ltd	*Generators; generator and station transformers*
W. T. Glover & Co Ltd	*Main and auxiliary cabling*
James Howden & Co Ltd	*Air heaters and exhauster fans*
Lancashire Dynamo & Crypto Ltd	*Motors and rectifiers*
Laurence Scott & Electromotors Ltd	*Motors*
Mather & Platt Ltd	*Circulating water pumps, sluice pumps, fire-fighting equipment*
Metropolitan-Vickers Electrical Co Ltd	*Automatic voltage regulators and motors*
Mitchell Engineering Ltd	*Coal handling plant*
Nalder Bros & Co Ltd	*Instruments*
Pirelli-General Cable Works Ltd	*Flexible busbars and connexions*
Premier Cooler & Engineering Co Ltd	*Hydrogen coolers*
A. Reyrolle & Co Ltd	*Main and auxiliary switchgear, protective equipment, instruments, workshop equipment*
Richardsons Westgarth Ltd	*Circulating water screens*
Standard Telephones & Cables Ltd	*Telephones and locators*
Stewarts & Lloyds Ltd	*Handrails, pipe-work, and valves*
Sturtevant Engineering Co Ltd	*Dust extraction plant*
Taylor-Tunnicliff & Co Ltd	*Insulators*
Transformers (Watford) Ltd	*Auxiliary transformers*
Wallace & Tiernan Ltd	*Chlorinating plant*
C. C. Wakefield & Co Ltd	*Oil handling plant*
G. & J. Weir Ltd	*Boiler feed pumps*
Worthington-Simpson Ltd	*Auxiliary pumps and air compressors*

Tilbury Power Station

This station, situated in Essex and close to the Thames Estuary, was originally planned for nine units. At present it houses six boilers and turboalternators, each rated at 60 MW, giving a total installed capacity of 360 MW. The first of the six units was commissioned in September 1956, and the sixth unit was completed 15 months later in December 1957.

The civil engineering work included a reinforced concrete jetty, 400 ft (122 m) long, with facilities for unloading coal which is delivered alongside in 4500-ton colliers. The upstream arm of this jetty, 300 ft (91 m) long, is arranged to accommodate plant for loading ash into seagoing barges.

The whole layout of the site has been planned to allow a second station to be constructed, on land which is at present undeveloped, downstream of the present station. This consideration has determined the design of the coal handling plant and the size of the main control room, offices, and workshops.

The coal handling plant—consisting of four jetty cranes, belt conveyors direct to the boiler bunkers or to store, and a reclaiming transporter—has a maximum capacity of 800 tons an hour, and each of the bunkers over the six boilers has a capacity of 730 tons.

In 1955 consideration was first given to the installation of equipment to enable a heavy residual oil to be burned as an alternative to coal. For this purpose, two storage tanks, each of 14,500 tons capacity, have been built, together with piping and pumps to take oil from 5000-ton tankers discharging at the jetty and to deliver it ultimately to the oil burners in the boilers at 500 lb/sq in (35 kg/cm²) and 280 deg F (138 deg C).

No 6 boiler was commissioned on oil; the other five have been using coal since they started operating and are being converted to oil during this year. For oil burning, the pulverized fuel burners and their connexions are removed from the boilers and replaced by oil burners.

Each boiler and turboalternator forms a single unit. Steam pressure is supplied by the former at 900 lb/sq in (63 kg/cm²) and 900 deg F (482 deg C), and the latter run at 3000 rpm and have a maximum and economical rating of 60 MW each. They are all three-cylinder machines with a double-flow exhaust; the first three are impulse-reaction type turbines, and the other three are reaction type.

The generators are cooled by hydrogen circulating at 0·5 lb/sq in (35 g/cm²), but No 6 is of special interest, as the stator is directly water-cooled by distilled water circulating through the windings. This is a prototype generator used to obtain experience of this system of cooling before it is applied to the very much bigger generators now being constructed for the CEGB and in which it is essential to keep the size of the generator within practical limits.

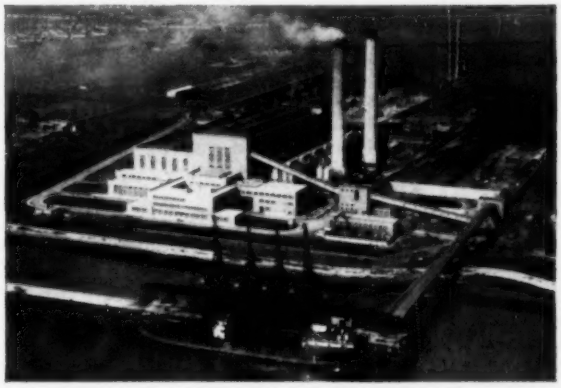
Each alternator generates at 11·8 kV and feeds directly into a transformer rated at 72 MVA which raises the generated voltage to 132 kV at full load. In addition, there are two station transformers taking their supply from the 132 kV switching station and feeding the 3·3 kV auxiliary switchboards in the power station. A unit transformer is also connected to each generator, and normally supplies the auxiliary power required for its own turbine and boiler unit.

The main 132 kV switchgear is outdoor equipment of the air-blast type, with a rupturing capacity of 3500 MVA.

Both this and the 3·3 kV switchgear are controlled from the main control room, where the switching and loading of the main generators and the switching of the 132 kV outgoing lines are controlled. This room also contains the controls for a 33 kV substation on the site, fed from the 132 kV system.

The Tilbury power station is now supplying electricity to the CEGB's 132 kV grid, and will ultimately supply the 275 kV supergrid.

The project became the responsibility of the British Electricity Authority on its establishment in 1948, and the design and construction of the station has been under the direction of the Eastern Divisional Controller of the CEGB.



Aerial view of Tilbury Power Station

The principal contractors and sub-contractors for the main and auxiliary electrical equipment included:

Daniel Adamson & Co Ltd	*Auxiliary boilers*
Babcock & Wilcox Ltd	*Ash and dust handling plant*
Brush Electrical Engineering Co Ltd	*Auxiliary transformers*
Chloride Batteries Ltd	*Station batteries and charging equipment*
Drysdale & Co Ltd	*Circulating water pumps*
English Electric Co Ltd	*Nos 1, 2, and 3 turboalternators, condensers, and feed heaters; generator and station transformers, 3·3 kV and 415-volt switchgear and 3·3 kV control panels*
General Electric Co Ltd	*33 kV control panels*
Mather & Platt Ltd	*Fire protection equipment and auxiliary pumps*
Metropolitan-Vickers Electrical Co Ltd	*132 kV control panels and switchgear*
Mitchell Engineering Ltd	*Coal handling plant*
C. A. Parsons & Co Ltd	*Nos 4, 5, and 6 turboalternators, condensers, and feed heaters*
Pirelli-General Cable Co Ltd	*132 kV cabling*
Standard Telephones & Cables Ltd	*Operator's desk in control room and operation telephones*
Stewarts & Lloyds Ltd	*Low-pressure pipe-work*
Sturtevant Engineering Co Ltd	*Vacuum cleaning plant*

Research for Industry

A SUMMARY of the work done during the 15 months to the end of 1957 by the 39 research associations and 7 research councils in receipt of a Government grant has just been issued by the Department of Scientific and Industrial Research.

The total combined income of the associations was £6 m, of which the Government grant provided £1·5 m, which included a special grant to the *Association of Special Libraries and Information Bureaux* (ASLIB) to help in acquiring the larger premises it needs.

From the range of activities detailed in the Report and covering such diverse industries as baking, printing, hosiery, leather (to mention only a few), we naturally select the body mainly responsible for research work in the electrical field—the *British Electrical and Allied Industries Research Association*, with its laboratories at Leatherhead, Surrey, and Perivale, Middlesex, and its field station at Shinfield Green, near Reading, Berkshire. Principal points from its report are as follows:

The transfer of the high power switch and control gear laboratories from Perivale to the new buildings at Leatherhead is under way, and a 2·8 million volt surge generator with a stored energy of 130 kilowatt-seconds has been installed in the new Leatherhead laboratories. Its associated measuring equipment includes a 2-metre sphere gap and some novel oscillographic and tripping devices. With this equipment it will be possible to carry out full-scale tests on the highest voltage apparatus likely to be used on transmission systems.

For investigation into surge propagation in transformer windings, a new recurrent surge oscillograph has been developed which has a special feature in that the injection unit can be placed very close to the apparatus under test. A lightning flash counter which may lead to a more satisfactory unit of assessment of lightning activity than the 'thunderstorm-day' has been devised in collaboration with Dr E. T. Pierce of Cambridge and has attracted considerable attention overseas.

Two investigations into the testing of circuit-breakers are being carried out: the first is concerned with the proper voltage division between units in series, and the second the practical application of a method of synthetic testing which was proposed a few years ago.

The programme on arc physics has shown very close agreement between theory and observation in the successive formation of cores within the arc column, and core temperatures of 40,000 deg K have been predicted and measured.

In the field of rural electrification, a two-day conference of 'Future Research on Applications of Electricity to Increase Food Production' was held during the year and was well attended by representatives both from this country and abroad.

There have been further advances in research on transformers, cables, safety and flameproof equipment, radio interference, heating, and domestic equipment. An analysis of certain features of the arc welding of aluminium in argon has been carried out in cooperation with the *British Welding Research Association*, and long-term investigations have just been started on stress rupture testing of steel bars and creep rupture of pipes maintained at temperatures around 750-775 deg C.

Here are brief details of the work of other associations whose research has a bearing on the electrical industry. The *British Shipbuilding Research Association* has a team located at the Atomic Energy Research Establishment, Harwell. This team has now been reorganized as a separate section of the Association, and active steps have been taken to keep the shipbuilding industry informed of research and developments in the marine application of nuclear energy.

The *Parsons and Marine Engineering Turbine Research and Development Association* (PAMETRADA) records steady progress in design improvements to marine turbine propulsion machinery, particularly in the use of higher speeds and loads for gearing. The new research building has now been equipped for investigations into noise and vibration in gearing, critical speeds, and hydraulic couplings. Space is also available for epicyclic gear brake research and development. Two members of the staff are permanently attached to the *British Shipbuilding Research Association* team at Harwell.

The new metallurgical laboratories of the *British Welding Research Association* at Abington Hall, near Cambridge, were formally opened in July of last year. Considerable research has been done on the weldability of various metals and alloys, including the higher strength steels, and aluminium and its alloys. Special equipment has been constructed to investigate fundamental aspects of the weldability of titanium and zirconium alloys. Research is also being carried out on argon-shielded methods of welding aluminium alloys, and on a new process of carbon dioxide-shielded welding for ferrous materials.

The *British Scientific Instrument Research Association* has extended its activities in the electronic field and has appointed a nuclear physicist to lead a team of specialists on nucleonic instrument development. Reports have been published giving information on the uses of semi-conducting devices in instruments and longer term tests are now in hand. Work on special flow meters is being concentrated on electromagnetic and ultrasonic methods.

The *Production Engineering Research Association* (PERA) reports that members have made wider and more effective use of all its research, information, and education services during the year. A new education and training department has been formed and a new research block has been occupied by production engineering research laboratories, workshops, and the metallurgy and metrology laboratories.

An interesting subject under investigation by the *Research Association of British Rubber Manufacturers* is anti-static rubbers. An important stage has now been reached and a technical manual surveying the whole subject and incorporating the extensive results of the Association's work has been published.

Research for Industry is published by HM Stationery Office at 7s 6d (by post 8s 1d); 1 dollar 35 cents, USA.

Notes

Royal Patron for Computer Exhibition and Symposium

HRH The Duke of Edinburgh has consented to be Patron of the Electronic Computer Exhibition and Symposium which will be held at Olympia, London, from 28 November to 4 December 1958.

The exhibition will be the first of its kind in the world, and more than forty British manufacturers of electronic computers and associated equipment have taken space. The symposium, which will run concurrently with the exhibition, will have as its theme the value of the computer as an aid to management, and the papers to be presented will be designed to give the business executive the latest information derived from up-to-date practical experience of the installation and operation of British computers and data processing systems in a wide variety of business applications.

Immediately preceding the exhibition and business symposium there will be a scientific symposium on computers organized by the National Physical Laboratory, to be held at the NPL, Teddington, Middlesex, from 24 to 27 November 1958. Admission to this event will be by invitation.

The organization of the exhibition and business symposium, which was initiated by the National Research Development Corporation, is in the hands of the Electronic Engineering Association (EEA) and the Office Appliance and Business Equipment Trades Association (OABETA). Further information can be obtained from the Exhibition Organizer, 11/13 Dowgate Hill, London EC4.

BCURA Annual Report

The annual report of The British Coal Utilization Research Association shows the wide field of investigations undertaken by the Association into problems associated with the use of coal.

With the coming into force of the Clean Air Act, means had to be found of measuring the amount of grit and dust emitted from chimneys. This work was substantially completed during 1957 and the findings will be published in a handbook which will be available shortly.

The Boiler Department has devised an improved method of controlling the air distribution through the fuel beds of chain grate stokers for shell-type boilers, and is developing a simple air/fuel ratio controller; in this and other Departments increased attention is now being given to the automatic control of firing appliances. The need to facilitate the use of small coal in place of graded or large-size coal has stimulated the work on improving the performance of mechanical firing equipment for industrial boilers.

Work carried out by the Association on behalf of the Boiler Availability Committee included tests at a number of power stations to evaluate means for inhibiting corrosion in boilers due to the condensation of acid. It also comprised laboratory studies on the release of chlorine, alkalis, and sulphur during the combustion of coal. Towards the end of the year, consequent upon the change in emphasis of the work of the Fuel Research Station, the BCURA was asked to extend its programme of research for this Committee.

Copies of the Annual Report, price 10s, may be obtained from the Liaison and Publications Officer, BCURA, Randalls Road, Leatherhead, Surrey.

New Factory for Gresham Transformers

At the recent opening of the new heavy transformer assembly factory at Twickenham, Middlesex, it was stated by Mr John P. Coleman, MIEE, Chairman and co-founder of Gresham Transformers Ltd, that the new building has been designed especially for heavy power transformers up to 5000 kVA for the Canadian market, where the company has, over the last three years, established a steady business.

He also drew attention to the fact that the new building has been equipped throughout with off-peak thermal storage floor heating, using heavy gauge 'Kumanel' wire elements operating at 55 V. The total load is 130 kW. The Electrical Research Association cooperated in planning the installation and has fixed a large number of thermocouples to observe the thermal behaviour under working conditions, from which it is hoped to accumulate some valuable data which will contribute to a study of this comparatively new form of space heating.

Mr R. R. B. Brown, BA, BSc, MIEE, Chairman of the Southern Electricity Board, formally declared the building open. Pointing out that the steady expansion of electricity distribution underlined the need for more transformers, he congratulated the company on its enterprise and deserved success. He also commended the new floor heating system as a valuable contribution to the off-peak load.

He was followed by Mr Peter Young of the Dollar Export Council, who spoke of his recent visit to Canada with the British Trade Commission and referred to the remarkable success which had been achieved by the recently formed selling company—Gresham Transformers (Canada) Ltd.

Thanking the two previous speakers, Mr Gresham Cooke, MP for Twickenham, added his congratulations to the company on their steady expansion and their contribution to the prosperity of Twickenham.

The Gresham Group now comprises: Gresham Transformers Ltd, Gresham Electronic Transformers Ltd, Lion Electronic Developments Ltd, Gresham Developments Ltd, Hughes (Taplow) Ltd, and the Gresham Lion Group Ltd.

The original company—Gresham Transformers Ltd—was founded in 1939 to manufacture high quality transformers, and one of their principal developments is the range of 'Lofel' low-loss transformers.

Laying an Under-water Power Line in Scotland

The steady expansion of the electricity supply in the area covered by the North of Scotland Hydro-Electric Board often means that the power transmission lines have to be taken across the lochs. Such a case occurred recently on the west coast of Scotland, where three underwater crossings were involved: one across Loch Fyne (thereby obviating a 62-mile (100-km) inland route), another across the Kyles of Bute, and the third from Lochalsh to the island of Skye. All these cables were connected to a 33 kV overhead land line.

The manufacture and laying of the cables were carried out by Siemens Edison Swan Ltd, who installed in their Woolwich works new plant especially designed to handle long lengths of cable—particularly submarine types—without factory-made joints.

In all, five paper insulated lead alloy covered single wire armoured cables were supplied, as follows: for the Lochalsh-Skye crossing, a 0·1 sq in (64·5 mm²) 3-core oval H-type, 1854 yards (1695 m) long; for the Loch Fyne crossing, three 0·1 sq in (64·5 mm²) 3-core round HSL type, each of 2750 yards (2515 m); and for the Kyles of Bute crossing a similar cable, 2000 yards (1829 m) long.

The overall diameter of the first cable was 3·96 in (10 cm) and its total weight 47·62 tons; the diameter of the second and third cables was 3·73 in (9·5 cm), and their weights were respectively 57·58 and 41·87 tons.

All these cables were manufactured in one continuous length—the first time, it is claimed, that submarine cables of 33 kV capacity have been made to such lengths.

Laying operations were successfully completed during the spring of this year, using the MV *Anno*—a shallow-draught vessel designed originally for the Newburgh-Fifeshire grain trade and chartered by Siemens Edison Swan Ltd for this operation.

MV Anno *taking the cables aboard at the Siemens Edison Swan wharf at Woolwich.* (*See story in third column*)

New Hydro-electric Scheme for Scotland

The North of Scotland Hydro-Electric Board has now received confirmation of its proposals for a new hydro-electric scheme in the Strathfarrar-Kilmorack area in the counties of Inverness and Ross and Cromarty. The scheme will cover a catchment area of 350 square miles (906·5 km²), and will involve the building of five dams and four generating stations to produce 261 million units of electricity annually. Its estimated cost is £14¼ million.

The Strathfarrar scheme is an important part of the North of Scotland Board's programme, which is designed not only to meet the increased demand for electricity that is expected in the Board's area but also to provide peak supplies of electricity to the South of Scotland Electricity Board, whose programme in turn assumes that these supplies will be available.

The capital cost of the scheme per kilowatt installed, based on present-day estimates, is higher than the corresponding cost of modern steam stations, but hydro-electric schemes have a much longer life. It is comparable with the capital cost per kilowatt installed at nuclear stations. The cost of generation is estimated to be 0·75d per unit. The scheme is designed for an average annual load factor of 29 per cent, which is approximately equal to the average annual load factor of the North of Scotland Board's system and is thus most suited to their requirements. New steam generating stations and nuclear stations are most economically run at much higher load factors, and the cost of production at a load factor of 29 per cent at a modern steam station would be 1·08d and at a nuclear station 1·63d; (in the case of a steam station, this assumes a continuation of present coal, labour, and other running costs). For these reasons the scheme is the most economical method of providing electricity at the load factor required by the Board.

A White Paper on the scheme is available from HM Stationery Office, or through any bookseller, price 1s.

Irradiation Service Offered by Metropolitan-Vickers

A new irradiation laboratory at the Metropolitan-Vickers Barton Works (some two miles from the main works at Trafford Park, Manchester) now enables the firm to offer an irradiation service to other firms and organizations interested in the possibilities of irradiation as an industrial process.

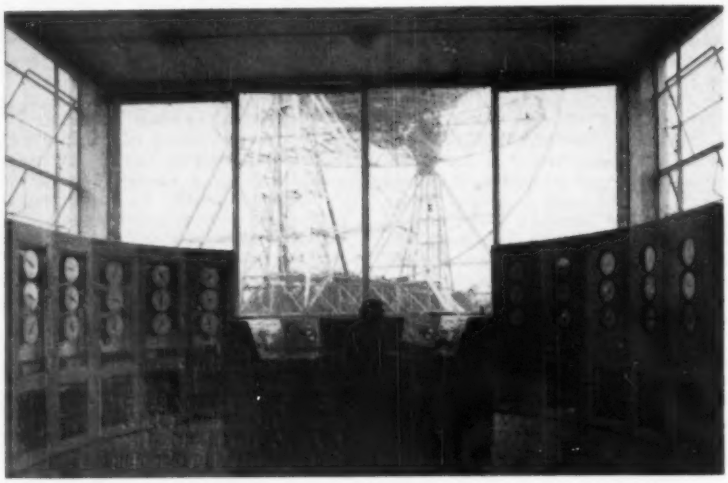
For applications such as disinfestation of grain; preservation of foodstuffs; sterilization of pharmaceuticals, dressings, and sutures; processing of plastics—including polymerization, cross linking, chain scission, and graft polymerization—irradiation has already been shown to have likely advantages, and for these and other possible applications the laboratory service will provide for specific investigations without involving interested parties in the purchase of their own equipment and the maintenance of trained personnel. The service will also cater for a limited amount of contract work.

The new laboratory is a self-contained unit, of special construction and interior layout. Its main item of equipment is a 4 MeV linear accelerator designed for irradiation techniques, and provision is made for the efficient handling of a wide variety of products under safe conditions.

A beam-scanner with an output window of pure aluminium foil is fitted to the accelerator. This enables the beam to scan an area of 12 in by ¾ in (305 by 19 mm) at the window. Greater areas can be covered either by adjusting the position of the scanner, in which case some loss of intensity occurs, or by passing the material through the beam several times, presenting a fresh area to the beam at each pass.

A variable speed conveying system is provided to allow the continuous passage of material through the electron beam, and a work holder giving 4 degrees of freedom is also provided for handling articles in small numbers or of irregular shapes.

The whole equipment is controlled from a station outside the accelerator room, and interlocks are fitted to all doors so that the equipment is rendered safe before access to the treatment and accelerator room is possible. The walls surrounding the radiation areas are constructed of thick concrete with 4 in (10 cm) steel facing in certain locations.



The Jodrell Bank radio telescope seen from the controller's room. The telescope is floodlit at night. The dials in the left-hand rack indicate galactic longitude, galactic latitude, sidereal time, right ascension and declination; those on the right indicate predicted azimuth, predicted elevation, universal time, actual azimuth and actual elevation

'The Inquisitive Giant'

The giant radio telescope at Jodrell Bank in Cheshire (described in THE BEAMA JOURNAL of November 1957) is the largest completely steerable radio telescope of its kind in the world, and the story of its conception and construction is vividly told in a film recently made by Anvil Films and produced by the Central Office of Information for world-wide distribution on television, in cinemas, and for other public showings.

The Jodrell Bank radio telescope may well rank as the major research instrument in radio astronomy for a considerable time to come, and it represents a unique achievement which considerably enhances Britain's prestige abroad as one of the world's main centres of scientific research and technological skill.

The film first traces briefly the development of the optical telescope from its original invention by Galileo; Sir Isaac Newton's first reflecting telescope; the work of William Herschel and Lord Ross, up to the largest modern telescopes—the 100 in (254 cm) and 200 in (308 cm) mirror telescopes at Mount Palomar and Mount Wilson in the USA.

The still new science of radio astronomy—first foreshadowed by Sir Oliver Lodge, who suspected that radio waves were reaching the earth from outer space—is then shown from its beginnings in the work of Jasuski and Grote Reber in the USA in the early 1930s, and its rapid development after the war through the work of Appleton and Hay in Britain, Bolton and Stanley in Australia, Ryle and Smith in Cambridge, and Hanbury Brown and Hazard at the Jodrell Bank experimental station.

But the equipment at this station was too limited in its scope to explore all the sky, and so Professor Lovell of the University of Manchester, in charge of the Jodrell Bank experimental station, put the problem to Mr H. C. Husband, a Sheffield consulting engineer, and on the recommendation of the Royal Astronomical Society, with the backing of the British Government and the generous support of the Nuffield Foundation, work on the project of the world's largest fully steerable radio telescope began.

The film then shows in highly interesting detail all the stages of design, development, testing, and construction of this remarkable piece of engineering, with its 250 ft (76 m) diameter bowl which alone weighs 750 tons (the complete structure weighs nearly 2000 tons), capable of being rotated in any direction to a very high degree of precision by electric motors controlled by an electronic system which counteracts the motion of the earth and enables the telescope to follow a star automatically.

It is believed that many of the radio sources which this telescope will study lie in outer space at distances of perhaps 2000 million light years. It can also be used as a transmitting aerial to study radio echoes

from man-made earth satellites. Prominent among the telescope's uses will be studies of the sun, and the physical and meteorological conditions in the upper atmosphere.

Inquiries about the film will be welcomed by the Central Office of Information in London or any of the British Information Services overseas.

'Conquest of the Atom'—a New Film

This film is a successor to *Mirror in the Sky* (*The Story of Appleton and the Ionosphere*), which was the first of a new series of films called 'History of Modern Science'. The latter came into being to supplement the very successful Advanced Science series of films which have been widely used for science teaching both in this country and overseas, and the purpose of 'History of Modern Science' was to stimulate a scientific interest among pupils in the middle schools who will provide the scientists and technologists of the future.

As in the case of *Mirror in the Sky*, production of *Conquest of the Atom* was financed by Mullard Ltd and the Educational Foundation for Visual Aids, and was similarly approved by Western European Union as an international co-production. Both films were made by Realist Film Unit.

Conquest of the Atom tells in simple terms how the structure of the atom was discovered; how the atom was split by Rutherford in 1919; how his work was carried further by Cockcroft and Walton, who split the lithium atom, and by Chadwick who discovered the neutron, enabling Hahn and Strassman to split the uranium atom in 1938. Diagrams show the process of nuclear fission and the production of energy from a nuclear reactor, and the film ends with a brief reference to nuclear fusion and Zeta.

Distribution of the film (33 mm Eastman colour, running time 22 minutes) is through the Educational Foundation for Visual Aids, 33 Queen Anne Street, London, W1.

Three-dimensional Mathematical Films

Some of the problems associated with the development of three-dimensional mathematical films were discussed at an open meeting of the Sciences Committee of the Scientific Film Association held recently in London.

The subject was introduced by Mr Trevor J. Fletcher, Lecturer in Mathematics, Sir John Cass College, London. Mr Fletcher said he had taken up this subject several years ago in order to assist his own visualization of many physical problems which could be represented by the solutions of sets of equations. His experience with the three-dimensional film had convinced him that this medium was not only excellent visual aid for classroom use but also a versatile research tool. The insight which these films provided into the depicted phenomena often suggested new lines of research.

After recounting the development of this type of film the lecturer explained some of the problems encountered when attempting the illustration, with the aid of this medium, of mathematical conceptions. These problems include such considerations as the cost of production, suitability for use in small classrooms, simplicity of manufacture, and the need for the producer to have had some considerable mathematical training.

The author overcame these limitations and restrictions by developing a system in which the stereoscopic pairs are made by projective drawing on quarto-sized paper. Each pair of drawings is then photographed side by side on 16 mm film. A single projector using a bicel lens can then superimpose the two images on to a metallized screen. The number of drawings required is not normally excessive, since a relatively crude or rough representation is sufficient for the observer to grasp the nature of the solution to the problem. It appears that an inherent difficulty with this system is the need for great accuracy in the production of the drawings, as an error of 0·01 in (0·25 mm) is apparently perceptible.

The lecturer explained that for educational purposes the projector system must be relatively cheap and simple to use. This automatically ruled out the use of two synchronized projectors with all the advantages of the full width of 35 mm film.

After the lecture the author showed a film which is believed to be the first English animated mathematical film in three dimensions. This film shows moving coloured diagrams of the lines of force when electromagnetic oscillations take place in resonant cavities. The film is in three parts, with each part showing, respectively, the H101, E111, and H111 modes of oscillation. The presentation of the diagrams stereoscopically on moving film brought out clearly features of the oscillation, which are difficult to grasp from a study of the mathematical equations alone. The production of the film, made possible by grants from the Nuffield Foundation, required lengthy computational work in addition to the actual preparation of the diagrams.

Mr Fletcher is to be congratulated on the successful development of a most interesting visual aid and research tool. There is reason to suppose that this type of film will also help non-specialists to appreciate and possibly understand many involved problems which would otherwise be incomprehensible.

'Electronic Applications Bulletin'

Philips quarterly *Electronic Applications Bulletin* contains articles dealing with the practical application of electronics in numerous fields. The April issue is of particular interest to process control and industrial heating engineers, since it contains two articles on RF heating and one paper on automation.

Of the first two, one article deals with the intermittent use of oscillator tubes in RF heating generators and shows that advantage can be taken of the intermittent operation of the oscillator to exceed the normal valve ratings; practical examples and curves are used to demonstrate this. The other article is a description, with calculations and diagrams, of an experimental 10 kc/s 10 kW industrial heating generator equipped with hydrogen thyratrons. The method is based on the use of hydrogen thyratrons acting as an electronic switch whereby the charge stored in a capacitor is suddenly transferred to a resonant circuit so as to produce a train of damped oscillations. The control circuit can be arranged so that repetition frequency varies with the load, and it is thus possible to reduce the output very greatly when the load is removed without affecting the operating conditions of the thyratrons.

'The Contribution of Electronics to Automation' is the title of an article based on a lecture given at the International Congress on Automation which was held in Paris in 1956. The paper discusses automation in its widest sense, the essential characteristics of electronic methods of automation, the reliability, maintenance and design of automation equipment, and the disadvantages and advantages of using electronic equipment for industrial purposes.

Valves for RF Heating

The English Electric Valve Company Ltd have developed a range of valves specially designed to withstand the stringent conditions associated with radio frequency heating. The large valve group, which have external copper anodes for forced air or water cooling, are for use in heaters of 4 kW and over; the small group provides for applications such as dielectric heating for plastic welding or preheating in RF generators developing up to 1·2 kW.

Very complete information on this series of power triodes and tetrodes, and mercury and xenon rectifiers, is given in a loose-leaf publication issued by the company and entitled 'Valves for RF Heating'. This gives for each valve technical data and information on cooling and operating conditions, with curves which include anode, control grid, constant current and air cooling characteristics. A novel transparent calculator is also provided by which operating conditions for any particular valve can be quickly worked out by using it in conjunction with the constant current curves, and to facilitate its use still further, a number of design sheets is also included.

Another interesting folder by the same company gives brief details of magnetrons and includes information on frequency range, output power, cooling and working conditions. Both these publications can be obtained free from the English Electric Valve Co Ltd, Chelmsford, Essex.

Recent Trade and Technical Literature

The Cambridge Instrument Company's new literature includes the following. List 144/B/1—Gas Analysers—covering panels for direct and differential analysis and accessories for panel mounting. List 149/1—Recording Accelerometers designed for the measurement of acceleration, deceleration, and vibration in a wide range of applications are described in this leaflet. A complete list of Cambridge Electrical Instruments with abridged specifications is given in leaflet 163/1. *The Cambridge Instrument Co Ltd, 13 Grosvenor Place, London, SW1.*

Crompton Parkinson's new range of series T fractional horse-power motors is described in a recent leaflet. Frame sizes and dimensions are tabulated and there are examples of typical performance. Issued by *Crompton Parkinson Ltd, Crompton House, Aldwych, London, WC2.*

A new brochure of Ferranti panel instruments gives details of the range of round and rectangular instruments covering moving coil, rectifier, thermocouple, moving iron and electrostatic types. *Ferranti Ltd, Hollinwood, Lancs.*

The BBC's Crystal Palace Television Tower

FOR more than eighty years the Crystal Palace stood as a symbol of mid-Victorian England. Built originally for the Great Exhibition of 1851, it was later moved from Hyde Park and, considerably enlarged, re-erected on the highest ridge of the Sydenham Hills. In November 1936 the Palace was totally destroyed by fire, and only rubble and twisted metal remained as a memory of its former glory.

After the war, the BBC recommenced its television broadcasts from the pre-war site at Alexandra Palace in the north of London. However, the height of the aerials—600 feet (183 m)—was insufficient to provide the full coverage which the BBC required for London and the Home Counties. A new and higher tower was needed, capable of supporting aerials at about 1000 feet (305 m) above sea level. BBC engineers eventually decided on the old Crystal Palace grounds.

As a result of competitive tenders, the BBC placed a contract with British Insulated Callender's Construction Company to develop the design, fabricate and erect a tower to the BBC's detailed specification of requirements.

While the design was being worked out in detail, aerodynamic stability tests were carried out on model sections of the tower by Imperial College and by the National Physical Laboratory. These sections, comprising the aerial-bearing structures of the tower built accurately to scale, were extensively tested in a wind tunnel, allowing observations to be made of their behaviour under all wind conditions.

Each of the four legs of the tower was to stand on a concrete pad, supported by six vertical and three raking concrete piles. Because of the proximity of the underground transmitter building, these piles had to be driven with the minimum of vibration, and therefore only the outside casing of the piles was driven into the ground. This meant that, when the hollow shell thus formed was filled with steel-reinforced concrete, an unstressed solid core resulted, giving the pile a greatly improved load-bearing ability.

A reinforced concrete pile-cap, 14 feet (4·27 m) square and 4 feet (122 cm) thick, was fitted over each group of piles. Inside each cap a steel grillage, fitted with heavy-gauge bolts to hold the leg base-plates in position, was concreted accurately into place.

Steelwork for the tower was fabricated at the Hereford factory of Painter Brothers Ltd—a member of the BICC Group. Special high grade steel—450 tons of it—was used in its construction.

On site, the foundations—including a number of concrete temporary guy anchorages—having been completed, the next stage was the erection of a derrick, 230 feet (70 m) high, in the centre of the tower base. This derrick was built of 20-foot (6·1-m) sections, hauled into position by means of two derrick poles attached temporarily to the top and moved higher as the derrick grew. A smaller derrick, 125 feet (38 m) in height, was built in the same way and was used in conjunction with the larger one for the initial stages of the work.

With the derrick erected, the construction of the tower began. The heavy steel base-plates were fitted into position over bolts projecting from the concrete pile-caps. On these base-plates and their concrete foundations, spaced at the four corners of a 120-foot (36·6-m) square, the whole weight of the tower rests. Next to be fixed into position were the main leg members of the first panel. Cruciform in section—so as to make the best possible use of standard angle sections—these were the heaviest components of the tower. When these were in place, the bracing members and span sections were partly assembled on the ground and hoisted into position, using the 125-foot (38-m) derrick. Temporary steel wire stays attached to concrete anchorages served to support the heavy steel corner members of each panel until the bracing connexions between them were completed.

Up to the 444-foot (135-m) level, the tower is similar in shape to the Eiffel Tower, and cruciform section steel girders are used for the main leg members. Above that height, the parallel sections carrying the aerial arrays have solid rod-section leg members.

At 429 feet (131 m), the leg members bend inwards, narrowing the tower to 9 feet 6 inches (2·9 m) square at 444 feet (135 m). The total height is 708 feet (216 m). An unusual feature of the construction of the tower was the large loads hoisted to great heights. Normally, the higher the lift, the smaller are the loads handled, but in this case loads of three tons were handled up to a height of 500 feet (152 m), and later a load of two tons was carried right to the top.

A permanent hoist, to convey the BBC's maintenance engineers to a platform just below the 400-foot (122-m) level, was constructed inside one of the legs of the tower. An unusual feature of this hoist is that, while the guide rails follow the line of the tower, the passenger cage remains vertical.

The upper part of the tower is designed to carry four sets of aerials. The lower 72 feet (22 m) of it support the Band I aerials. Above these is space for two sets of Band III aerials, and right at the top of the tower is a 40-foot (12-m) high helical Band V aerial for experimental UHF broadcasts. Provision is also made for the installation of parabolic aerials to receive outside broadcast transmissions.

Shortly after the completion of the tower, scientists of the National Physical Laboratory carried out a series

of tests designed to confirm calculations of its aerodynamic stability. Twelve rockets, each giving a thrust of half a ton, were affixed to the tower and fired at intervals timed to coincide with the natural frequency of the structure. Remotely recording instruments attached to the tower gave measurements of tower movements, and from these an assessment of the ability of the tower to absorb energy from vibration, due principally to friction in bolted joints, could be made.

From the top of the tower, which is the highest unstayed structure in Great Britain, one can see to Hampstead in the north, the North Downs in the south, to Windsor in the west, and eastwards to Gravesend. This wide visual horizon, together with one of the most powerful television transmitters in the country—200 kW effective radiated power—enables the station to give television coverage to 15 million viewers in London and the Home Counties.

Quality – Its Creation and Control

AT a press reception at the Institution of Production Engineers, the Earl of Halsbury, FRIC, F Inst P, MI Prod E, introduced a report—'Quality, its creation and control'—which is the result of two years' work by a sub-committee set up by the Institution.

'Ever since the battle of Agincourt, possibly earlier . . . the British have got results by relying on quality rather than quantity' Lord Halsbury said in his introductory remarks, pointing out that Britain relied on the high quality of its goods to achieve a good export market. He reminded us that in the nineteenth century Britain became the workshop of the world, and in the rush for mass production the virtues of individual craftsmanship were largely forgotten. It was now time to re-create in to-day's workmen the pride of workmanship of the eighteenth century, and Lord Halsbury believed that by doing this we should produce for the export market a better grade of product very economically and at the same time our workmen would become a happier class of people.

The recommendations of this 45-page report are based on replacing the inspection department of a factory by a quality department which would have a preventive rather than a curative effect on production. The responsibility for the quality of a product must rest with the production side of the workshop and not with the inspection. This should produce better goods with less scrap.

One of the most important sections of the report deals with 'Operator Control'. The operator of any particular machine should be made responsible for the quality of the goods he is producing and should be encouraged to look for quality as well as quantity in production. On the shop floor, operator control may be applied in several ways including: (1) the introduction of instruments on the machines which show the size of dimensions as they are being produced, so enabling the operator to control the exact size of the work in progress; (2) the introduction of inspection equipment adjacent to automatic and semi-automatic machines for checking dimensions immediately after production while the machine produces the following pieces, so that checking is carried out within the machine cycle time. With operator control, where every production operator is his own inspector, a more realistic balance of costing between production and inspector will be possible. The training of operators is of prime importance, and this task should be shared by the production and quality departments' personnel.

The report points out that in order to produce a successful approach to the creation of the quality departments, positive action must come from director and top management level. Replying to a question, Mr S. W. Nixon (The Rover Co Ltd) said that training of quality engineers would vary from firm to firm, at least until quality engineering had become established; but he could envisage the time when technical colleges would run degree courses in quality engineering.

The quality department must be given the status necessary to carry out its new broad functions as a contribution to the execution of management policy, and it must therefore be an equal partner with the other major departments of the organization. It should be equipped to advise the drawing office where production design is incompatible with the quality required and should be able to supply information to production and design management at all stages during the production of a product and should also be able to advise them on the capacity of machines on the shop floor. Too often the cost of a product is raised when design asks for tolerances of 0·001 in (0·025 mm) to be produced on machines capable of only 0·003 in (0·075 mm). The scrap resulting at the inspection stage may raise costs to a very large extent.

The report concludes that successful achievement in the field of quality demands and depends upon prompt action. One of the principal functions of the modern quality department is to furnish authentic information, and unless advantage is taken of this to generate immediate corrective action where the need for it is indicated, a major opportunity to achieve improvement would be lost. The management should exhibit constant interest in the achievement of quality in order to stimulate the corresponding interest at all levels in the organization.

The sub-committee responsible for this interesting and provocative report are Mr R. K. Grunau (Rolls-Royce Limited), *Chairman*; Mr S. W. Nixon (The Rover Company Limited), *Vice-Chairman*; Mr H. R. Daddow (Simms Motor Units Limited), Mr W. H. Hitchman (Paul Escare Limited), Mr C. H. Johnson (Hoover Limited), Mr I. R. Smith (Bristol Aircraft Limited), Mr E. Summerscales (Joseph Lucas Limited), Mr G. W. Turner (Hoover Limited).

The report is available from the Institution of Production Engineers, 10 Chesterfield Street, London, W1, price 10s.

'Open Days' at the NPL

THE annual 'Open Days' at the National Physical Laboratory are widely welcomed by the large number of visitors who take advantage of this opportunity of seeing a representative display of the great variety of important work carried out at the Laboratory.

Recently, there has been a reorganization of several of the divisions; the work formerly undertaken by the Electricity, Metrology and Physics Divisions has been redistributed among three new Divisions: Standards, Applied Physics, and Basic Physics, with the object of making it easier to introduce new basic researches and to concentrate the work on fundamental standards.

The Caesium Resonator

Among the latter are standards of measurements, of which those of length and mass, time-interval and frequency, electromagnetic quantities, and temperature are basic. The Standards Division is responsible for the caesium resonator—the so-called 'atomic clock'—which is accurate to one part in 10^{10}. Set up some two years ago, this is giving good service as a primary reference standard of frequency. It is interesting to note that in a recently completed comparison, in conjunction with Harvard University, between the NPL caesium standard and a similar American standard, the difference was less than one part in 10^9. A new and improved caesium resonator is now being built, and a transportable model has just been constructed which promises to provide a basic laboratory standard.

The important standard of the velocity of propagation of electromagnetic waves as determined by the 72 Gc/s (4 mm wave) four-horn interferometer has been evaluated as $C_0 = 299{,}792{\cdot}50$ sd 0·10 km/s. The basic length standard was the red line of the cadmium spectrum. The Division is also developing a new absolute method of determining 'g' —the acceleration due to gravity.

Considerable work has been done on basic electrical standards, and new determinations of inductance, resistance, and current are in hand. In the High Voltage section, the modifications to the 500 kV absolute voltmeter have been completed, and equipment is being constructed to enable errors of voltage transformers to be measured to an accuracy of one part in 10^4.

New Test Transformers

The new 1 million V test transformer and its ancillary equipment are now installed and have passed acceptance tests. A compressed gas capacitor of 1 MV working voltage is due for immediate delivery, and the equipment for a 1 MV dc supply in conjunction with the new test transformer has been successfully operated.

The Control Mechanisms and Electronics Division (CME) was founded in 1954 by amalgamating two existing groups working respectively on automatic controls, and the design and development of automatic digital computers. CME's main purposes are to initiate and improve automatic controls for experimental, industrial, and administrative operations, and to evolve techniques and equipment for data processing and computation.

Fastest Magnetic Drum

The first digital computer—the ACE pilot model—was completed in 1951, and the new full-scale ACE is now nearing completion. It will have mercury delay lines and magnetic drums for the storage of numerical data and instruction sequences, and both punched card and magnetic tape equipment for input and output. A prototype magnetic drum has been successfully operated and has proved to be one of the fastest drums in existence; accurately synchronized to the computer, it runs at 12,000 rpm and information is recorded on its surface at 100,000 digits per second.

A small group is studying the application of digital computers to business operations—work which should lead to the discovery of new data-handling techniques and the development of special equipment. Other groups are engaged in the development of automatic and semi-automatic equipment for the reduction of experimental data, and in the study of automatic control and servo-techniques for use in the industrial field.

Although much of the work of the Aerodynamics Division consists of long-term research in connexion with aeronautics and aircraft design, an increasing amount of investigation is now undertaken on problems of industrial aerodynamics. This work is divided broadly into wind effects on structures, and the dispersal of smoke from chimneys and funnels. Under the first heading, projects included the BBC's television tower at Crystal Palace,* and the proposed suspension bridge for the road crossing of the River Forth. Tests such as these call for highly accurate scale models demanding an impressive standard of craftsmanship.

Hypersonic Wind Tunnels

With the continually increasing speeds of aircraft and the development of guided missiles, new wind tunnels have become necessary. Hypersonic flight introduces a number of new physical problems resulting from the extremely high temperatures produced, and experiments at hypersonic speeds are difficult because the accelerated air cools and may liquefy. Plans are therefore in hand to build one wind tunnel using pre-heated air to about 800 deg C which will give a Mach number of 10, and another using unheated helium (which liquefies at a much lower temperature than air) to give Mach numbers up to 20.

* See page 132 of this issue.

Book Reviews

Programs for an Electronic Digital Computer. *2nd Edition. By M. V. Wilkes, D. J. Wheeler, and S. Gill.* $9\frac{1}{4} \times 6\frac{1}{4}$ in (235 × 159 *mm*). *Pp. xiv* + 238. *Illustrated. Index.* (*Massachusetts: Addison-Wesley*, 1957.) Price 60s net.

The advent of digital computers has brought a spectacular increase in the number of complicated engineering and mathematical problems amenable to numerical solution. Problems that were thought to be intractable until quite recently are now being solved as a matter of routine. The subject of programming, or of presenting a problem to a machine in a form that the machine can understand and solve, is an all-important one, and has not received adequate attention to date. In presenting a second edition of this well-established book, the authors have successfully taken the opportunity of thoroughly revising the earlier edition in the light of their subsequent experience on other digital machines. With a field as rapidly developing as that of digital computers, it is not surprising that little of the original material has been taken over unchanged.

The basic digital computer used as a model for programming purposes is the EDSAC (Electronic Delay Storage Automatic Computer), located at Cambridge. The EDSAC is a single-address binary machine, whose order code lends itself fairly well to the purposes of a book on programming, being straightforward and fairly easily memorized. As the methods described can be readily translated into order codes for other machines, the scope of the book is obviously not limited to cover the EDSAC machine alone. In fact, a sound introduction to programming is given for any machine of the stored-programme type.

The basic parts of the EDSAC are described in Chapter 1, which cumulatively introduces the majority of the order code, including jump orders, pseudo-orders, and modification. The design of sub-routines and the use of private and library sub-routines are discussed in Chapter 2, which also contains a description of further parts of the order code, including overflow indication. An introduction to programming for digital machines other than EDSAC is given in Chapter 3, which contains an outline of minimum-access coding as used in conjunction with machines fitted with magnetic drums as their main stores. Input and output are the subject of Chapter 4, which includes details of the use of punched tape and punched cards. A few of the more frequently used sub-routines are discussed in Chapter 5, which contains useful sections on the solution of ordinary differential equations and the use of Chebyshev polynomials for the economization of power series. Methods for the location of errors in programmes are given in Chapter 6, while Chapter 7 gives five examples of complete programmes for EDSAC; one of these examples is particularly interesting, namely the calculation of a double-entry table for an integral containing two independent parameters. Automatic programming is the subject of Chapter 8, which covers programme assembly, a comparison of conversion and interpretive schemes, and a discussion on the acceptance by digital computers of formulae written in ordinary mathematical notation. Finally there are two large sections devoted respectively to specifications of the EDSAC library sub-routines and to detailed programmes of selected EDSAC library sub-routines.

Programming can only be learned by practice, and the authors have included specimen solutions of examples for the reader. This is a valuable feature that was not included in the previous edition, and is welcome. It is very convenient to have the library sub-routines available, and with their use, the reader will be in a position to tackle quite complicated problems.

It is interesting to observe that the authors do not like minimum-access coding, but are prepared to tolerate it so long as it enables relatively cheap machines, fitted with magnetic drum stores, to compete in speed with more expensive machines using random-access stores. Personally I agree wholeheartedly with this statement, but it is certainly a controversial issue. On the subject of autocoding, however, it is my view that the authors have underestimated the potential use of this important technique. While it is true that numerical analysis is necessary for all programming, and that an autocode programme is slower than a detailed programme, it is also true that many engineering problems are of a 'one-off' type, where solutions are not wanted for an extensive range of the parameters involved. In such cases it may be the programming time, and not the machine time, that is the basic cost item. An autocode programme may then be preferable to a detailed programme as it is distinctly shorter to write, and at the same time it can be error-free at the first attempt. Furthermore, the whole of the autocoding process can be grasped in a matter of hours without any prior knowledge of the machine in question.

To sum up, this is a first-rate book on programming for any computer of the stored-programme type, and gains in stature by not avoiding controversial issues. The printing could be a little firmer, but the presentation is excellent. I can thoroughly recommend the purchase of this book to anyone interested in the subject.

H. GOLDENBERG

Symposia Series on Networks and Circuits. *Microwave Research Institute: Polytechnic Institute of Brooklyn.* $8\frac{1}{4} \times 6$ *in* (222 × 152 *mm*). (*New York and London: Interscience Publishers*, 1958.) Price 40s net.

Over the period covered by the dates April 1952 to April 1956 the Microwave Research Institute of the Polytechnic Institute of Brooklyn, with the cooperation of other US professional and Government organizations, has held six symposia on matters connected with network synthesis and analysis, information networks, and microwave techniques, in the field principally of communication engineering, and the six books under review have been published as the *Proceedings* of the meetings. Each volume contains the full text of all the papers presented at the symposium to which it relates.

The papers themselves are too numerous to record individually in this review so that we will simply refer to the separate volumes by title and indicate briefly their scope.

Vol I is on Modern Network Synthesis within the audio to microwave field. It contains 20 papers which, individually, discuss such topics as topologic and algebraic considerations, function theory, driving-point impedances, four-poles, two-terminal-pair and *n*-terminal pair networks, electrolytic tank techniques, conformal mapping, electromagnetic field problems, equivalent networks, scattering matrix formulation, and several others relating to amplifiers, waveguides, and filters.

Vol II is concerned with Nonlinear Circuit Analysis and it contains 21 papers. Some of the more noteworthy are on mathematical methods in nonlinear vibration, the stability theory of difference-differential equations, acceleration plane method for nonlinear oscillations, amplitude stability of a power oscillator, synthesis of nonlinear systems, steady state vibrations in systems having arbitrary restoring and damping forces, the magnetic amplifier as a nonlinear circuit element, numerical analysis by the number series transformation method, and the analysis of nonlinear control systems with random inputs.

Vol III is on Information Networks and it contains 21 papers. Of these, special mention may be made of those on general filters for separation of signal and noise, transmission line characteristics and effects on pulse transmission, the arithmetical specification of messages and the determination of corrective networks, generalized concepts of networks, structure in communication nets, electrical responses from the auditory nervous system, logical approach to the design of computer circuits, topology applied to switching circuits, information conservation and sequence transducers, and design of digital coding networks.

Vol IV deals with Modern Advances in Microwave Techniques and contains 23 papers. In this, Professor Weber's Historical Notes on Microwaves provides a most valuable record of what has been done so far (November 1954) in this connexion. Other outstanding papers are concerned with recent advances in microwave tubes, new advances in guided propagation, space charge effects in travelling wave tubes, low-noise electron beams, gyrator networks, directional coupling in reciprocal systems, network methods in microwave measurements, the guiding and radiation of surface waves, analysis of coaxial line with a helical dielectric support, and artificial dielectrics for microwaves. There are also papers dealing with klystrons, magnetrons, millimetre tubes, ferrite devices, and waveguides.

Vol V is a second contribution to Modern Network Synthesis, containing 25 papers of which the following call for special mention. There are three papers on the synthesis of passive, nonreciprocal, and active networks respectively, and two others relating to

networks containing two kinds of elements and to conference networks. There are also two papers on impedance synthesis. Interesting applications of matrix theory are contained in papers on pseudo-scattering matrices, algebraic and topological foundations of network synthesis, duality and contact-transformations, reciprocal passive two-ports, and transmission through 4N poles. Others deal with time domain synthesis, time domain filters, sampled signals, the Laurent Schwartz distribution theory, Chebyshev rational functions, network response at imaginary frequencies, theorems for transistor amplifiers, synthesis of active filters, transistor amplifier neutralization, and feedback systems with time delay.

Vol VI is a second contribution to Nonlinear Circuit Analysis and contains 25 papers. Among these may be mentioned in particular the following: nonlinear oscillations, subharmonic response of ferroresonant circuits, half-wave magnetic amplifier circuits, three frequency resonance, equivalent linearization of control systems, digital computers in feedback system synthesis, sampled-data control systems, piecewise-linear analysis and synthesis, nonlinear resistive 3-poles, and complex convolution applied to nonlinear problems.

The omission of references to other papers in the foregoing is no reflexion on their quality, for they are all of a very high order of excellence. It would need much more space than is available to do full justice to each of them.

Most of the papers have considerable mathematical content and, according to the needs of the study, use is made of the calculus, network differential equations, determinants, matrices, function theory, operational methods, topology theory, probability theory, network theorems, complex algebra, conformal mapping, and steady-state and transient network equations.

These volumes bring right into the forefront not only the considerable value of well-organized symposia of expert collaborators but also of the publication of the papers in book form. This is a practice which should become more widespread and we hope that the widest publicity will be given to this excellent work of the Microwave Research Institute.

The books are lithoprinted on good quality paper and they are pleasingly free of the indifferent quality of both preparation and reproduction that sometimes accompanies such works.

S. AUSTEN STIGANT

Linear Algebra for Undergraduates. *By D. C. Murdoch.* $9\frac{1}{4} \times 6$ *in* (235×152 *mm*). *Pp xi* + 239. *Illustrated. Index.* (*New York: John Wiley; London: Chapman & Hall*, 1957.) Price 44s net.

The contents of this book are intended to provide an undergraduate with an elementary, concrete, and rigorous course in linear algebra. It introduces the reader to harder conceptions about the way transformations and manipulations of linear sets of equations may be performed. Although the book is purely mathematical and does not deal with any application of the principles in technology, the standard of mathematical knowledge required of the reader is only that of any first-year student in any faculty of science or technology.

The book has been written to provide students of science and engineering, in particular, with some knowledge of linear algebra, matrices and quadratic forms, as well as providing a background study for more advanced courses. The actual scope of the book covers a wide range of topics, such as vectors and vector space, matrix algebra, transformation of coordinates in a vector space, reduction of quadratic forms, and vector space over the complex field.

The text is illustrated by 22 line diagrams, and there are 302 well-chosen exercises, with answers, to enable the reader to gain experience in manipulating the linear analysis involved in solving purely mathematical problems.

The format, printing, and binding are attractive features of this new book, which has a well-written text. It is thoroughly recommended as an excellent introduction to a most important subject.

P. F. S.

A History of Mathematics. *By J. F. Scott.* 10×7 *in* (254×178 *mm*). *Pp x* + 266. *Illustrated. Index.* (*London: Taylor & Francis*, 1958.) Price 63s net.

This book is an eminently readable account of the developments of the main ideas in mathematics that have taken place from antiquity to the early nineteenth century, and it well brings out the preponderating importance of the work done in the later phases of mathematical history. Indeed, '. . . but a few centuries have elapsed since man first learned to handle such powerful computational aids as decimals and logarithms, to say nothing of the calculus, or geometrical methods'. To-day, there is in mathematics, as in many other branches of science, a high degree of specialization resulting from the rapid discoveries that have been made during the past hundred or so years, and it is intensely interesting to read of how these have been built up from the days of the ancient Babylonian and Egyptian civilizations.

The book opens with a brief account of mathematics in the antiquity (from roughly 5000 BC) of the Sumerians, the Egyptians, and the Babylonians, and proceeds to a review of the beginnings of Greek mathematics from about the sixth century BC, when there flourished the School of Pythagoras, Plato and the Academy, and the School of Alexandria; the invention of trigonometry from about the second century AD; the decline of Alexandrian science following the death of Ptolemy in the second century AD; the dark ages which set in about the fifth century and the revival in the seventh; and mathematics in the Orient commencing in the sixth century. There then follows an account of mathematics during the Renaissance (from the beginning of the fifteenth century) from Regiomontanus (1436–76) to Descartes (1596–1650); the seventeenth century and new methods in geometry; and the rise of mechanics beginning towards the end of the sixteenth century.

A survey is next given of the invention of decimal fractions (initiated towards the end of the sixteenth century), logarithms (seventeenth century), and the calculus (seventeenth century), followed by a chapter on Newton's discovery of the binomial theorem in the seventeenth century and the preparation of the *Principia Philosophiae* published in 1687, and one on the development of analytical methods commencing with the eighteenth century. The next chapter covers the period from Euler (1707–83) to Lagrange (1736–1813), and the remaining two discuss respectively the beginnings of modern geometry (from the second half of the eighteenth century), and arithmetic, the Queen of Mathematics.

Appendices give brief biographical notes on the mathematicians and other scientists named in the text and also mathematical notes on some of the topics referred to in the last four chapters of the book.

As we move over the centuries in this book, the text is enlivened by interludes on a variety of facets of the civilizations of the periods and the parts they have played in the mathematical inventions and developments of their time, these taking the place here of the more personal records of the foibles of the actors on the mathematical stages of the world such as have been given in other mathematical histories.

We cannot be other than intensely grateful to Dr Scott for having made available this absorbing record of researches which must have entailed a tremendous amount of hard work, clearly backed by high scholarship and turned by enthusiasm into a labour of love.

The printers and publishers are to be congratulated upon having produced such an attractive volume, an aesthetic appreciation of which is so much enhanced by the wide margins of its pages. We feel sure the book will be received with delight by all those interested in mathematical histories.

S. AUSTEN STIGANT

Switchgear Principles. *By P. H. G. Crane.* $8\frac{1}{2} \times 5\frac{1}{2}$ *in* (216×140 *mm*). *Pp vii* + 238. *Illustrated. Index.* (*London: Cleaver Hume Press*, 1957.) Price 25s net.

The best recommendation for any book on switchgear is surely that its author should have some connexion with the Electrical Research Association, for that body has carried out vital work on switchgear research and its contribution in this field of engineering is unrivalled.

The author, who has been associated with the ERA for many years, has produced a brief but admirable general handbook on circuit-breaking, and has had regard to the problems encountered in recent years in the design, manufacture, and testing of the extra high voltage switchgear, such as that for 275 kV, now being required in increasing quantities.

It might well be assumed that any electrical engineer with a sound training, and even a moderate range of experience, would be aware of the basic principles of short-circuit calculation and of the elements of protective gear; but with the large and complex switchgear installations, including air-blast gear with stacks of interrupters in series, it is not reasonable to expect that

more than a few engineers will have encountered the particular problems they present. Here, this book will be found to be especially useful. The interpretation, for example, of tests made on circuit-breakers so large that they cannot be tested as a whole, but must be given separate current and voltage tests on their constituent units, is a subject on which the newer generation of engineers joining the manufacturers and the supply authorities' organizations will no doubt need every possible guidance. This is supplied by Mr Crane.

He gives a number of references in an appendix, and practically the only critical suggestion we venture to offer him is that he has taken no account of the many papers presented to CIGRE on switchgear development. His guide to further reading is, in any case, a little meagre.

The book deals first with basic principles, including the theory of the arc discharge, and then touches on oil circuit-breakers of all kinds, and air circuit-breakers, both low voltage and high voltage, with some useful chapters on ancillary equipment, such as current and voltage transformers, and the accommodation of switchgear, concluding with a section on tests and specifications.

J. H. M. S.

Generation, Transmission and Utilization of Electrical Power. *4th edition. By A. T. Starr.* $8\frac{3}{4} \times 5\frac{1}{2}$ *in* (222 × 140 *mm*). *Pp xi* + 529. *Illustrated. Index.* (*London: Sir Isaac Pitman & Sons*, 1957.) Price 27s 6d net.

The main revision to the fourth edition is in the rearrangement of Chapter 1, which now includes an outline of the Calder Hall nuclear power station and an additional appendix which gives a short technical explanation of the principles of utilizing nuclear energy for the generation of electricity. With the exception of these important additions, very little of the original text has been revised; also many of the photographs of power stations (Battersea, for example) and equipment are the same as were used in previous editions. Although the examples set in each chapter have been carefully selected as being of the most practical value to the reader, a number of questions has been taken from examination papers of the early thirties which may not now represent the present standard needed for these qualifications. These criticisms do not in any way lessen the value of the book to the student and practical engineer; in fact, the text covers very clearly a considerably wide field for a volume of its size, and the treatment of each chapter is such that the reader should find no difficulty in understanding even the most difficult subject.

Generation of electricity by nuclear, steam, and water power is the subject of Chapter 1; there are discussions on the choice of site, operational costs, and technical details of power plant. Several chapters are devoted to transmission and distribution, covering design, switchgear, voltage regulation, short-circuits, and many other associated problems. Illumination, electric traction, and industrial utilization are covered in successive chapters, and heating, welding, and electrochemical processes by an appendix. The other appendices contain résumés of the theory of alternating current, transformers, and Thevenin's theorem, and a brief summary on metering and converting plant. While the publishers have succeeded in keeping the price at a reasonable figure, the author has managed to produce one of the few technical books which does really do the job of covering the Engineering Degrees Syllabus on Electric Power.

Introduction to the Geometry of Complex Numbers. *By Roland Deaux.* $9\frac{1}{2} \times 6\frac{1}{4}$ *in* (241 × 159 *mm*). *Pp* 208. *Illustrated. Index.* (*London: Constable*, 1958.) Price 37s 6d net.

This book is the outcome of lectures given since 1930 to students taking electromechanics at the Faculté polytechnique de Mons and 'it is addressed to beginners . . . who . . . have not considered the use of complex numbers for establishing geometric properties of plane figures'. It has three chapters which, respectively, deal with geometric representation of complex numbers, elements of analytic geometry in complex numbers, and circular transformations, and each contains a number of separate but associated 'articles' related to the main subject.

From the fundamental operations and transformations of complex numbers in geometry in Chapter 1, the book proceeds to discuss the straight line, circle, ellipse, cycloidal and unicursal curves, and conics in Chapter 2, and homography, the similitude group, and antigraphy in Chapter 3. Exercises to be worked out are given throughout the book. The text is clearly written and it is arranged in good sequence. For those electrical engineering students who find they are called upon to deal with vector and circle diagrams the book is useful, but, as they will realize when they encounter such terms as crunode, homothety, anallagmatic, antigraphy, they will need to learn the language of rather more than elementary mathematics. It will, however, be well worth while doing so.

Practical Electroacoustics. *By M. Rettinger.* $8\frac{1}{2} \times 5\frac{1}{2}$ *in* (216 × 140 *mm*). *Pp iii* + 271. *Illustrated. Index.* (*London: Thames & Hudson*, 1955.) Price 63s net.

The author in his preface says of sound in general that it is 'real, yet elusive; intricate, yet intriguing'. The engineer concerned with almost any aspect of high fidelity sound reproduction soon finds that this is true. Whereas in most other fields of electrical engineering the answer to a problem is exactly achievable, with a definition usually beyond question, the 'naturalness' or fidelity of one form of reproduction of sound is in no real way comparable with that of another; taste and other indefinable subleties intrude into the equations and upset the electroacoustic applecart. Nevertheless, there is a highly developed science of electroacoustics, and Mr Rettinger is obviously a foremost exponent of it, for he comes from the Engineering Department of the Radio Corporation of America. He very wisely does not attempt to define high fidelity; but what he does do is to give the reader the clearest possible guidance as to the component equipment by which it may be produced.

The book is naturally divided into treatises on microphones, loudspeakers, circuits, public address systems, and architectural acoustics. Each section is illustrated by examples drawn from current American practice. It is unfortunate that, as with so many American text-books, the author almost entirely neglects the vast literature on any technical subject produced outside the United States.

This is a most valuable book not only for all those engaged in this branch of engineering, but also for the interested lay reader—a recommendation applicable to few text books on any engineering subject.

J. H. M. S.

The Ultra High Frequency Performance of Receiving Valves. *By W. E. Benham and I. A. Harris.* $8\frac{3}{4} \times 5\frac{1}{2}$ *in* (222 × 140 *mm*). *Pp ix* + 173. *Index.* (*London: Macdonald*, 1957.) Price 28s net.

In the proverbial nutshell this book describes the important factors in the uhf behaviour of valves and it shows how they depend upon each other. The authors' objects in writing it have been first, to present the theory of the conventional valve as a circuit element, and second, to give a simple detailed account of the electronic processes in a valve. Thus, on the one hand it then becomes possible to apply linear circuit analysis to the problem of valve amplifiers for small signals at uhf, while on the other a sound introduction is provided to the transit time theory of thermionic devices and to the mathematical technique necessary for investigating new problems within the range of uhf theory.

The first chapter gives a general survey of the present problems, and Chapter 2 discusses the current in an inter-electrode space. Chapters 3 and 4 deal with the small-signal hf characteristics of idealized basic diodes, and of ideal triodes and tetrodes respectively. The behaviour differences between actual and ideal valves are shown in Chapter 5. Chapter 6 deals with induced currents in retarding fields and Chapter 7 with the retarding field diode. The valve as a two-terminal-pair circuit element is considered in Chapter 8. The last two chapters relate, respectively, to large signal theory and to the calculation of noise factor. These last develop from a new analysis of the effect of elastically reflected electrons from the anode of a triode on the signal and noise characteristics. Seven appendices and an index complete the book.

The work has a considerable mathematical content but of no great difficulty, and it is assumed that the reader is acquainted with valves, amplifiers, mixers, and circuit analysis.

In the Foreword Professor H. E. M. Barlow commends the book 'to those who are seeking to understand principles, particularly in relation to the part played by valves as circuit elements'. We endorse this recommendation, for the book is clearly the outcome of an intimate and up-to-date

knowledge of both fundamentals and practical developments.

High Voltage Circuit-Breakers. *By Vladislav Zajic.* 8 × 6 *in* (203 × 152 *mm*). *Pp* 324. *Illustrated. Index.* (*London: Constable*, 1958.) Price 25s net.

So many technical books, excellent in themselves, lack only one thing: an international viewpoint. The examples of practice used by their authors to illustrate the argument so often stem from the work of only a single nation. It is therefore refreshing to find that Mr Zajic has sat astride the Iron Curtain and has freely drawn on examples of switchgear design from both East and West. Therein, indeed, lies the main value of the book: in itself it provides a clear and exhaustive treatise on the theory and practice of high-voltage switchgear design, but this could have been paralleled elsewhere in British, American, and (no doubt) Russian textbooks.

Mr Zajic (in this excellent translation from the Czech by Mr J. R. Kavanova) first analyses typical high-voltage networks from the point of view of circuit breaking, and then launches into a full-scale descriptive section, in which every sort of circuit-breaking device is described, and usually illustrated. His cut-away sectional diagrams come from America, Great Britain, France, Sweden, Belgium, Switzerland, Germany, Czechoslovakia, and the USSR. An interesting description of the Czechoslovak Ministry of Heavy Industry Switchgear Testing Station is given, showing that the layout is at least as comprehensive as any equivalent stations in Great Britain.

The author draws freely and indiscriminately on sources of literature in Soviet-bloc countries and in the rest of the world. The bibliography, however, is unexpectedly short and meagre, but the references to individual papers are scattered throughout the text.

The book, in spite of its paper covers, is well produced in every way. It sets out the very latest current practice in switchgear design and testing. No further recommendation could be needed.

J. H. M. S.

Matrix Theory for Physicists. *By J. Heading.* 8¾ × 5½ *in* (222 × 146 *mm*). *Pp xi* + 242. *Index.* (*London: Longmans*, 1958.) Price 35s net.

There is no doubt that matrix theory has now 'caught on' with theoretical physicists and engineers and that, in the senior ranks at least, it is firmly rooted as a necessary aid to much investigational procedure. There is equally no doubt that, together with tensor analysis, matrix theory is destined to occupy a rôle of increasing value in applied physics and engineering science, although, as so often happens, applications of the fundamental mathematics have taken many decades to reach fruition. Happily, present-day students have all that behind them and for their guidance there are now such texts as the one under consideration.

The author of this book is a mathematician and, very naturally, the text is written largely in the phraseology of the mathematician. On the other hand he exhibits a considerable knowledge of physics and an ability to link these two branches of science together in such a way as to benefit both parties. Here, the mathematician *partners* the physicist and is not disdainful of another science which is not wholly contrived of pure thought.

The first two chapters of the book are devoted solely to those parts of matrix theory that are necessary for an understanding of the applications that follow. That is to say, they are concerned with fundamental definitions and operations and avoid the more abstract formalisms, which can be read elsewhere. In particular, Chapter 2 discusses in some detail the subject of characteristic roots and vectors, as these are important in many physics and engineering studies.

The remaining five chapters are all on applications. They cover geometry, mechanics, electromagnetic theory, the special theory of relativity, and quantum mechanics, and the author makes the very pertinent comment 'it is assumed that the reader is familiar with the physical background of the theory discussed'. How very true and how very necessary! In these chapters the author has set out to present familiar concepts in matrix notation and to develop the theory using matrix operations. In doing this he has made as comprehensive a selection of topics as possible and has also chosen them for their simplicity in order that the student can easily follow each step in the argument. He (the student) is also able to check the matrix method with other better-known methods as the investigation proceeds. Determinants and cartesian tensors are included briefly where they touch upon the main subject of the book.

Examples to be worked out by the student are given at the end of each chapter and the work is concluded with a bibliography and index.

The mathematical standard necessary for reading the book is that usually acquired in any first-year ancillary mathematics course given to degree students in physics.

This is a very ably written book and it is one that we can fully recommend to those young physicists, engineers, and mathematicians who wish to study matrix methods—as, of course, they all should! It is well printed and produced and very moderately priced. Decidedly an asset to the library of any mathematical physicist.

S. AUSTEN STIGANT

Synthesis of Passive Networks. *By E. A. Guillemin.* 9¼ × 6 *in* (235 × 152 *mm*). *Pp xviii* + 741. *Illustrated. Index.* (*New York: John Wiley; London: Chapman & Hall*, 1957.) Price 120s net.

We have already had two 'network' books from Professor Guillemin, *The Mathematics of Circuit Analysis* (1949)* and *Introductory Circuit Theory* (1953),† both of the highest calibre in content and presentation. In the preface to the latter book the author said that it was 'the first of a contemplated sequence', and the book now under review is the second of the sequence. Advanced aspects of network analysis and synthesis will be dealt with in later volumes, the next one evidently with the probable title *Special Problems in Network Synthesis*.

In these books the keynotes to the author's efforts have clearly been thoroughness and depth of presentation in an effort to combat a not unnatural tendency in students towards acquiring only a superficial understanding of the subject sufficient to meet immediate needs. While one has every sympathy with the student in the dilemmas which now must face him almost daily, it is the teacher's business and great responsibility to ensure that, on his part, nothing is lacking that at least will provide a full and well-proportioned three-dimensional account of the subject under consideration. That is precisely what is done in Professor Guillemin's three books.

The present volume deals mainly with realization theory and methods which, of course, form the basis of any synthesis technique. In fact, thirteen of the fifteen chapters are devoted to these, the remaining two relating to the approximation problem in the frequency and time domains. The first two chapters discuss the properties of driving-point and transfer impedance functions of RLC, LC, RL and RC networks. The next two deal with the synthesis of LC, RC and RL driving-point impedances. These are followed by a chapter on equivalent and reciprocal networks. Chapters 6, 7 and 8 relate, respectively, to the properties of two terminal-pair networks, synthesis of lossless two terminal-pair networks, and real-part sufficiency of an impedance or admittance.

Chapter 9 gives the methods of Brune and Darlington for driving-point impedance synthesis, and Chapter 10 deals with the Bott and Duffin and the Miyata methods of realization. Chapters 11 and 12 are concerned with various methods of transfer function synthesis, while Chapter 13 is devoted to the same subject in respect of RC networks. The frequency-domain aspects of the approximation problem and the time-domain synthesis of the same are discussed in Chapters 14 and 15, employing Butterworth, Chebyshev, and elliptic functions as well as Fourier and semi-infinite slope methods, and potential analogue interpretations. The usual index completes the work.

Each chapter is concluded with a set of problems for working out by the student, no answers being given, as mostly they are not of the kind where only a numerical solution is required. The work is exceedingly well illustrated and printed and it is one that compels our unqualified admiration. There is no doubt that when the series contemplated by the author is completed, the student and specialist will have a very fine network library at his command.

The printing and general format of the book are unexcelled, and particular commendation should be given to the craftsmanship of the line drawings. Although the price of the book is high it nevertheless represents good value for money—nearly 750 pages of first-rate instruction which could hardly be bettered.

S. AUSTEN STIGANT

* THE BEAMA JOURNAL, January 1951.
† THE BEAMA JOURNAL, November 1954.

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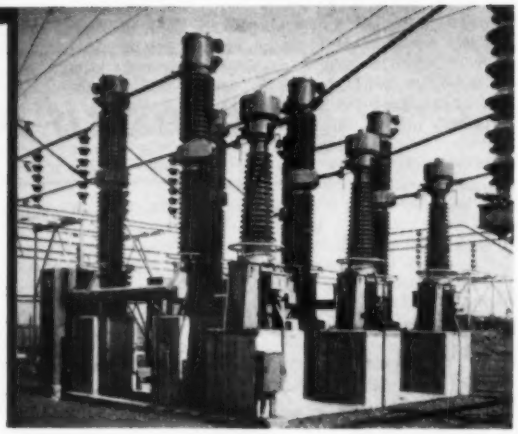

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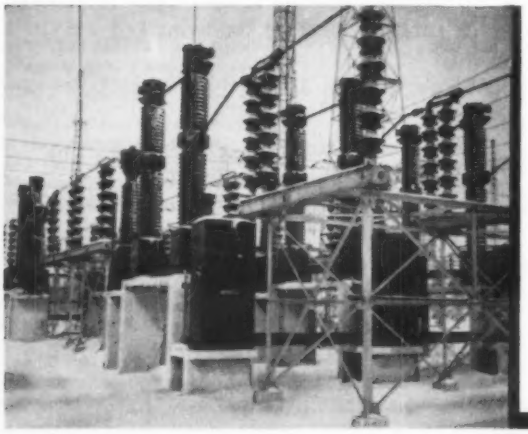

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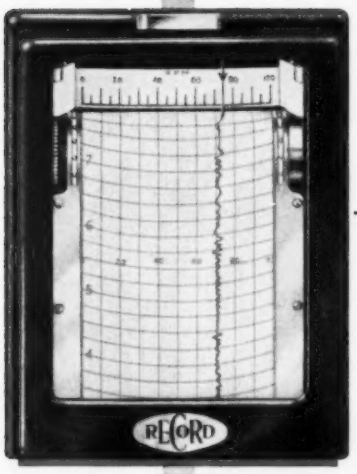

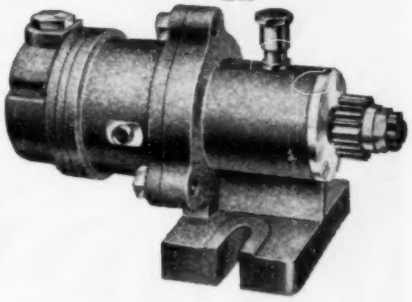

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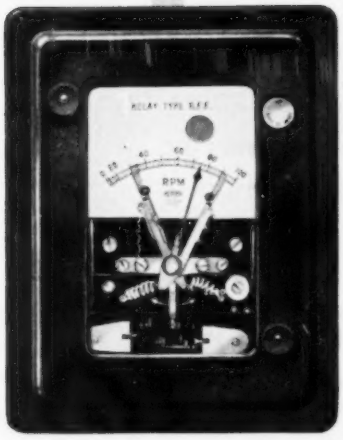

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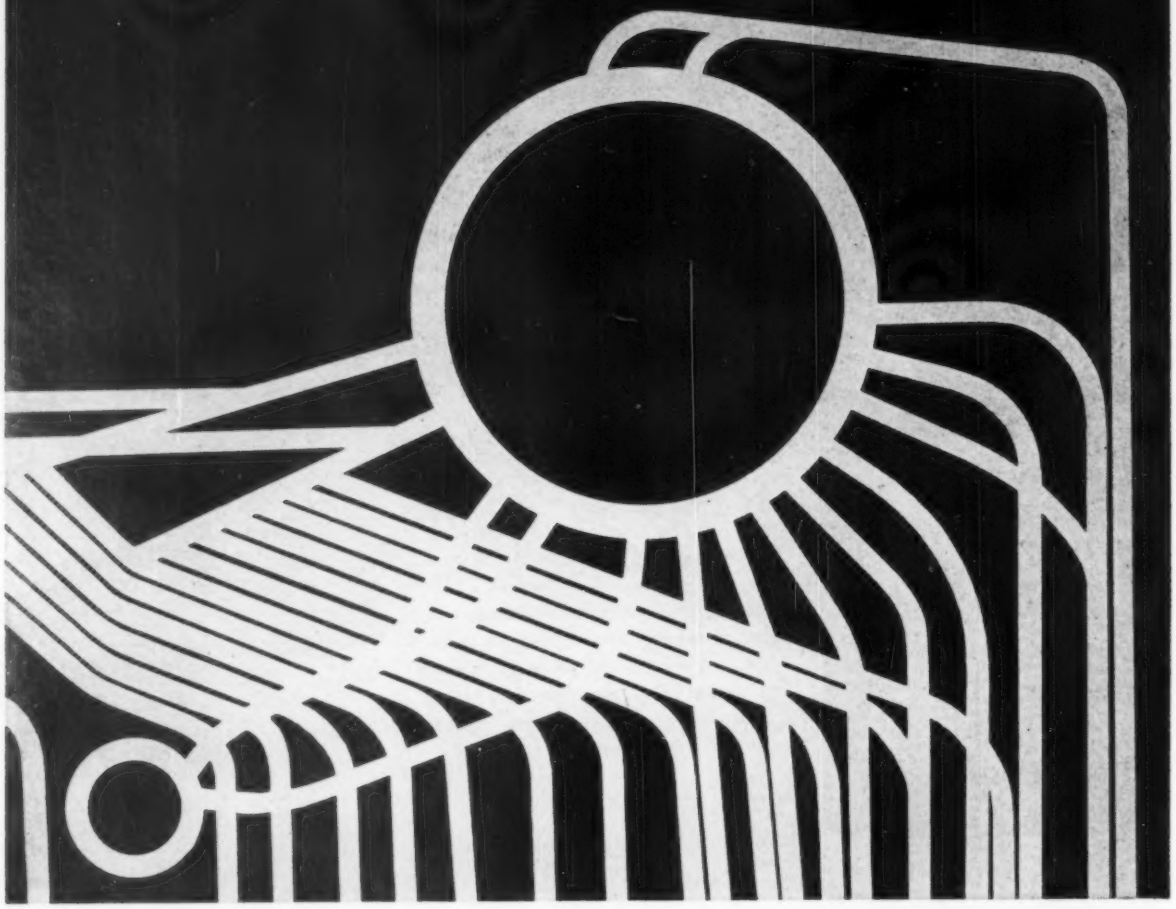

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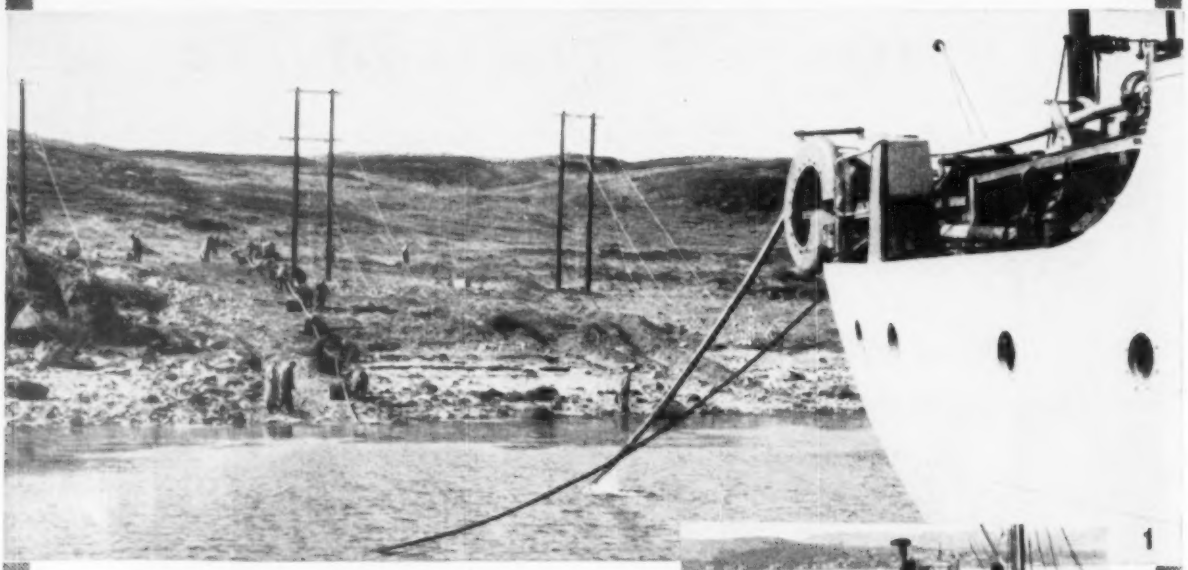

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1. *Loch Fyne: Landing one of the three cables with the overhead land line in the background.*
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3. *Loch Alsh: The shore end being hauled in by manual labour owing to the difficult terrain.*

2

3

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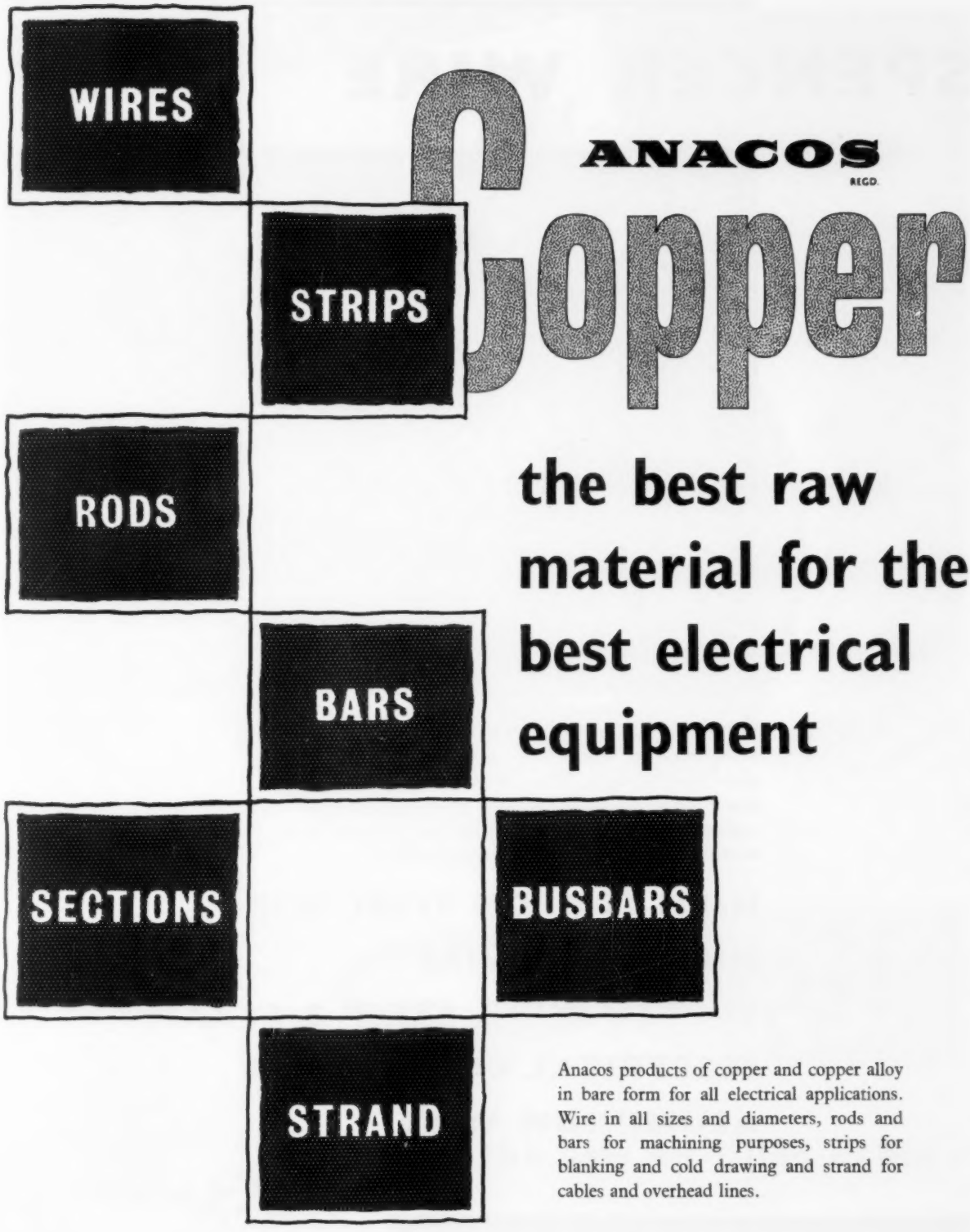

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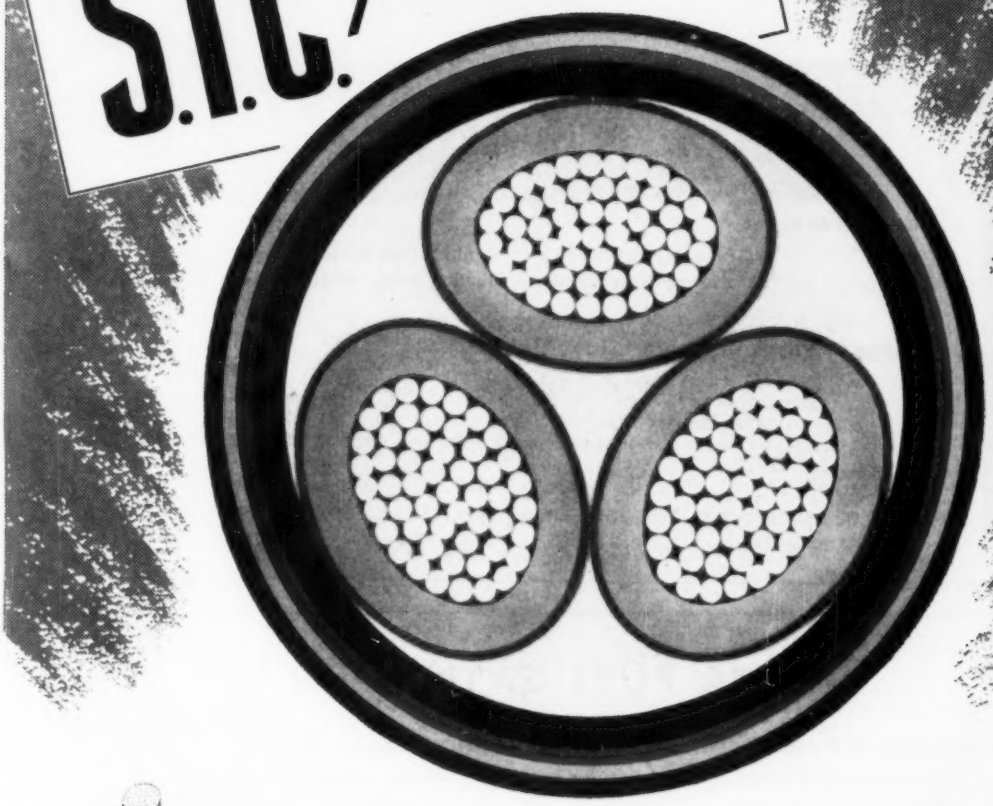

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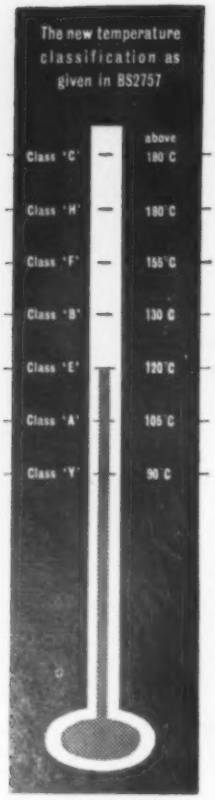

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FACTORS GOVERNING ELEMENT TEMPERATURE Element temperature depends on two factors (1) the surface area electrical loading (usually expressed as watts per sq. in. of resistor surface area) and (2) local heat dissipating conditions. While the first can be determined accurately for any piece of equipment, the second is subject to many influences such as type of mounting, dimensions of spiral, circulation of air around the element. It cannot easily be determined exactly. The rate at which heat can be dissipated or removed from the element governs the surface area electrical loading that can be allowed. Thus certain types of water heaters and space heaters using a forced draught may be loaded to a high watts density, while an enclosed oven element may have a low watts density.

TESTING ELEMENT MATERIALS As a basis for determining desirable element temperatures, and hence suitable electrical loading, a wire of the material to be tested is held horizontally in free air and used as a datum during the test. The result of this test is known as the 'straight wire free air temperature'. Equivalent temperatures have been worked out to enable data based on this temperature to be related to many types of element.

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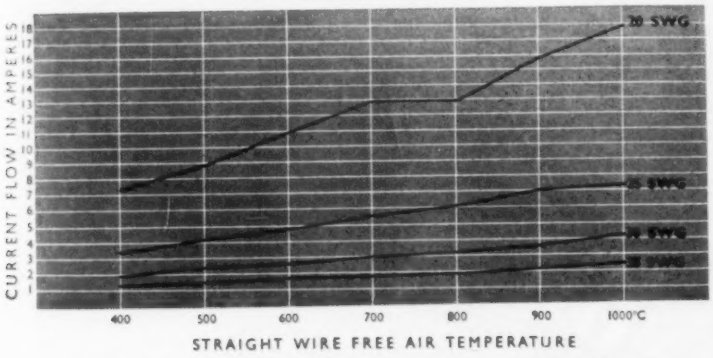

Graph showing Straight Wire Free Air Temperature/Current Flow for Brightray C

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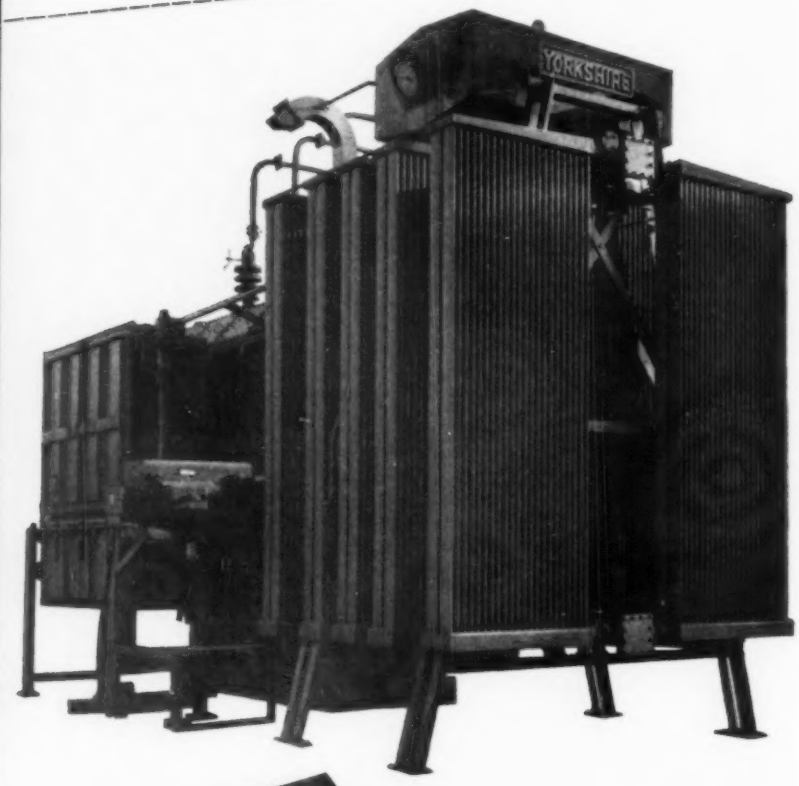

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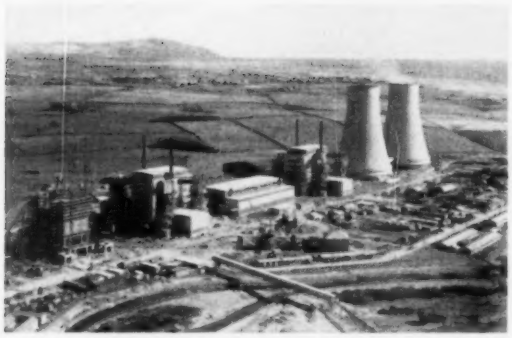

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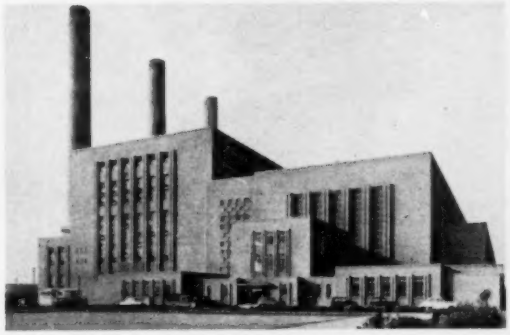

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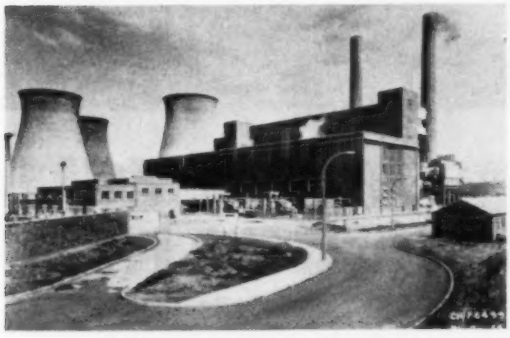

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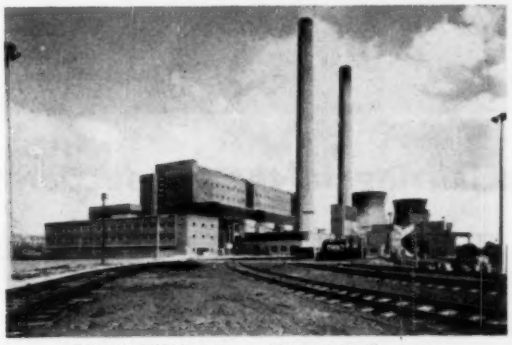

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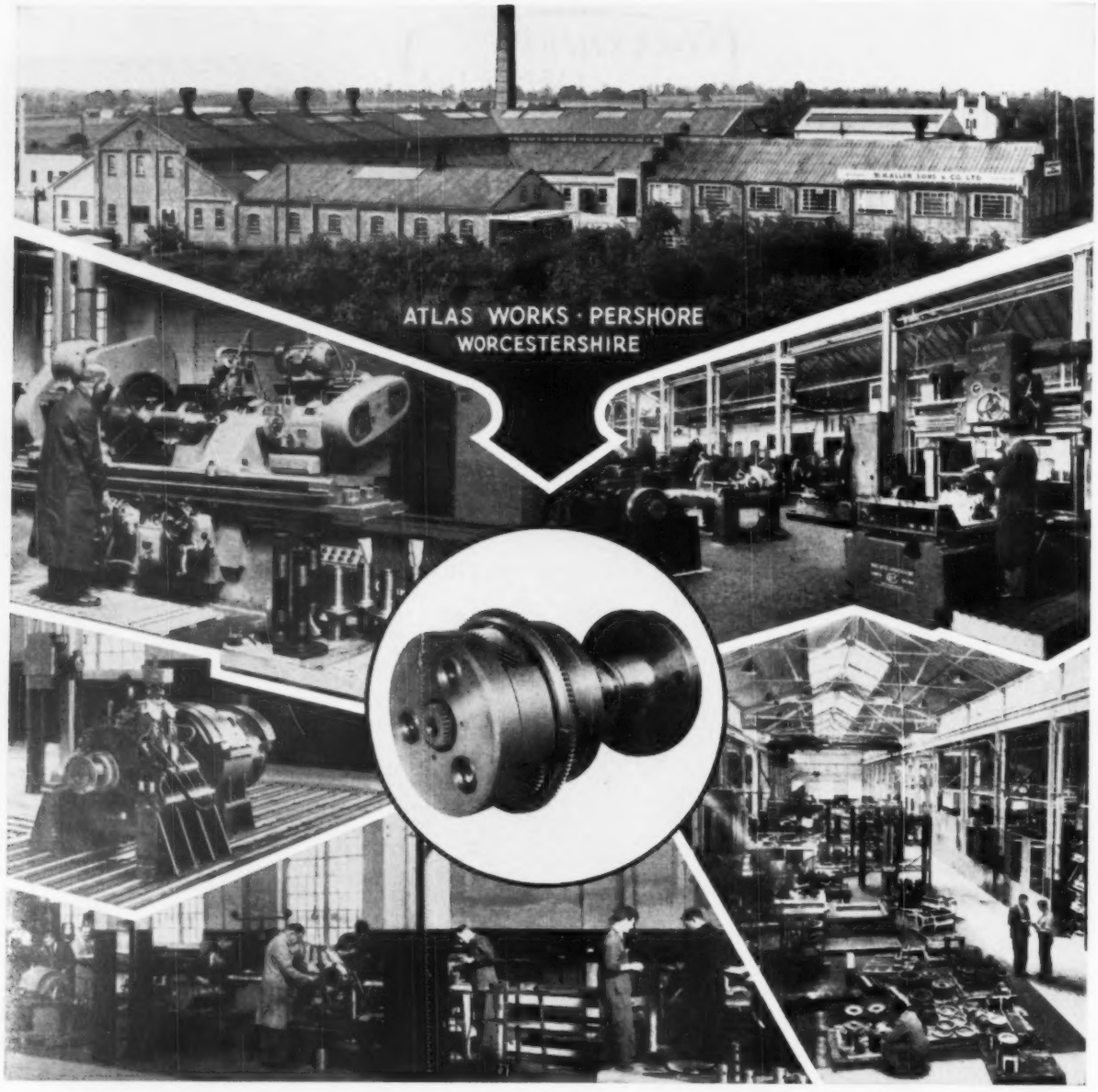

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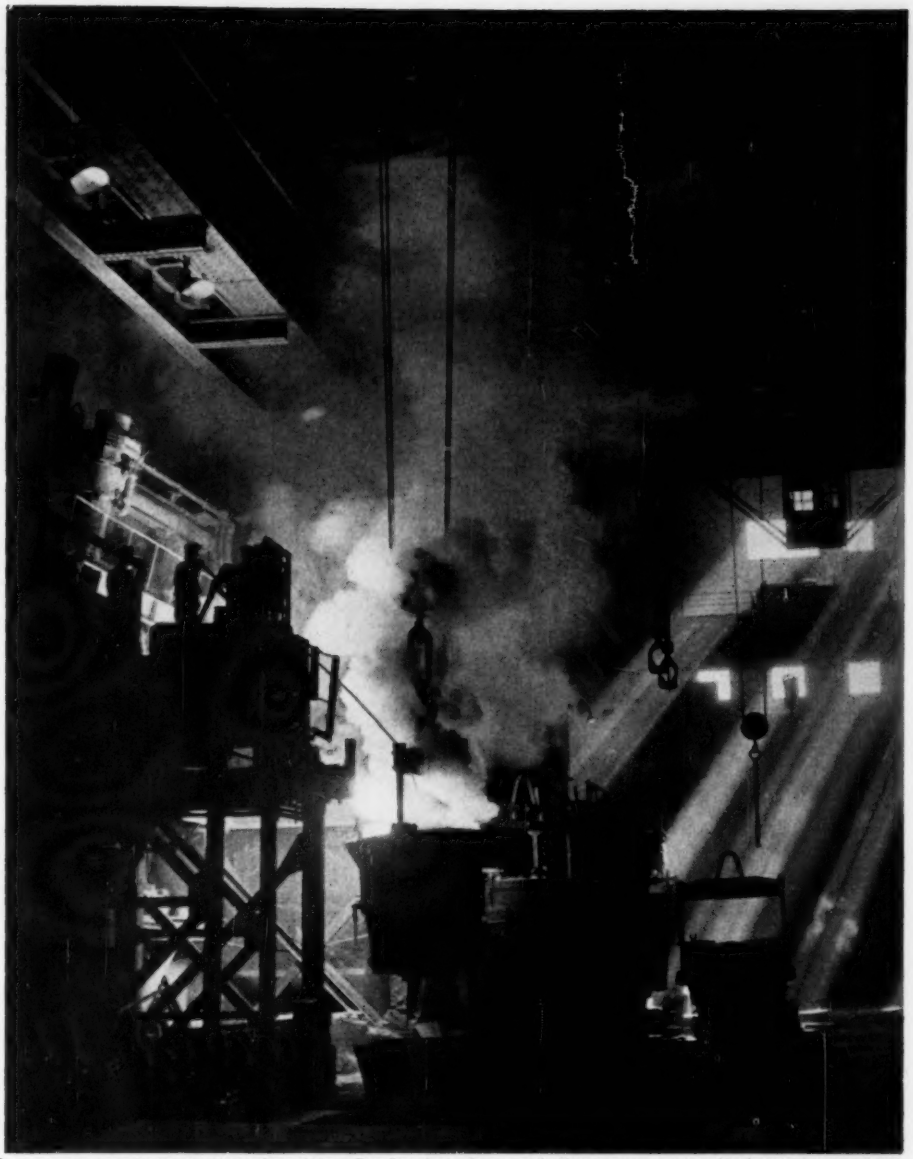

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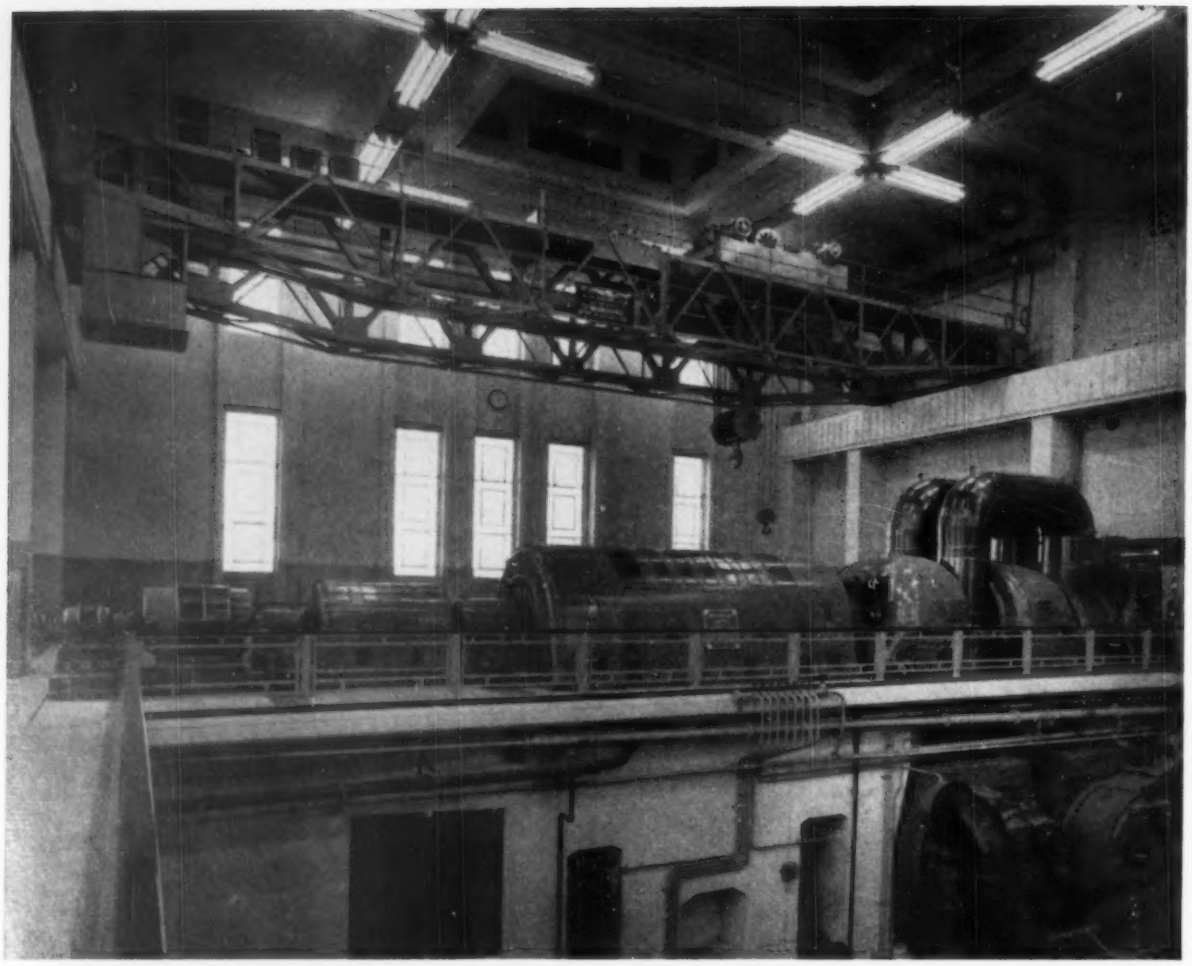

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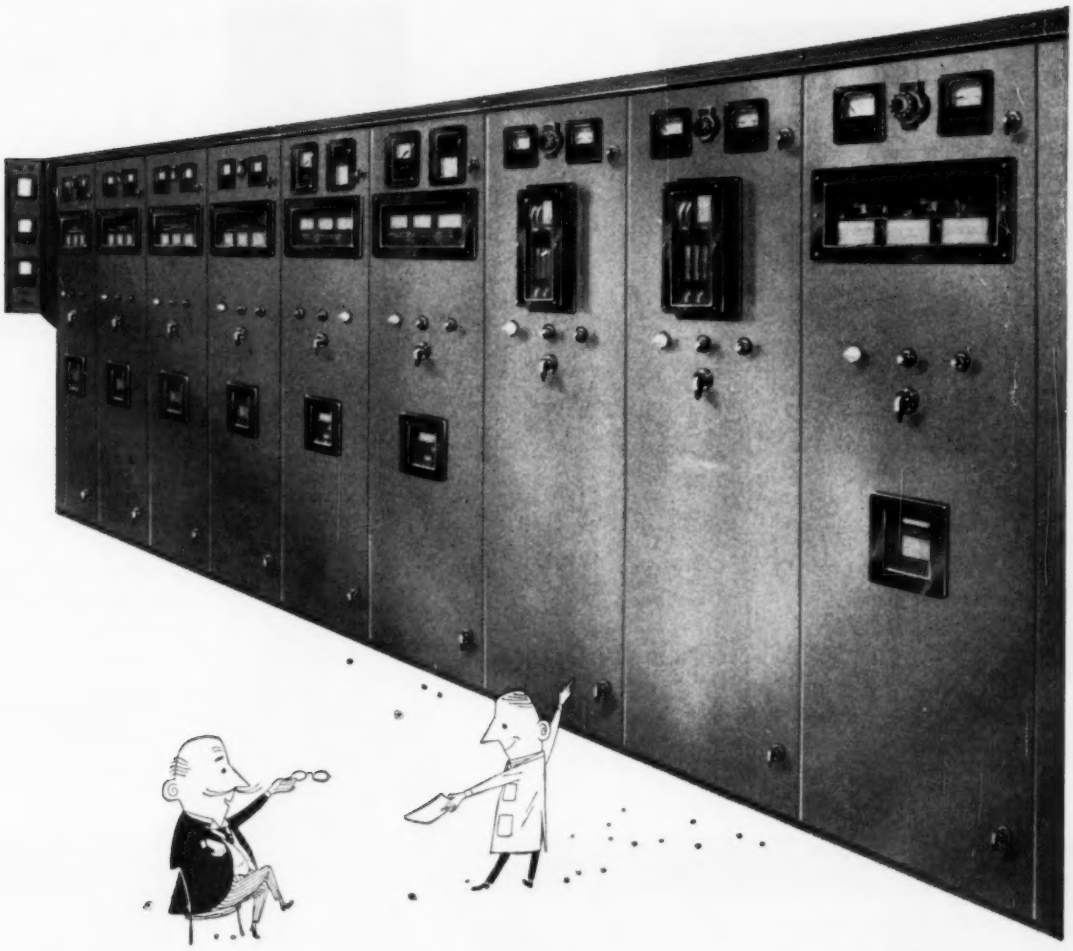

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with shaped conductors

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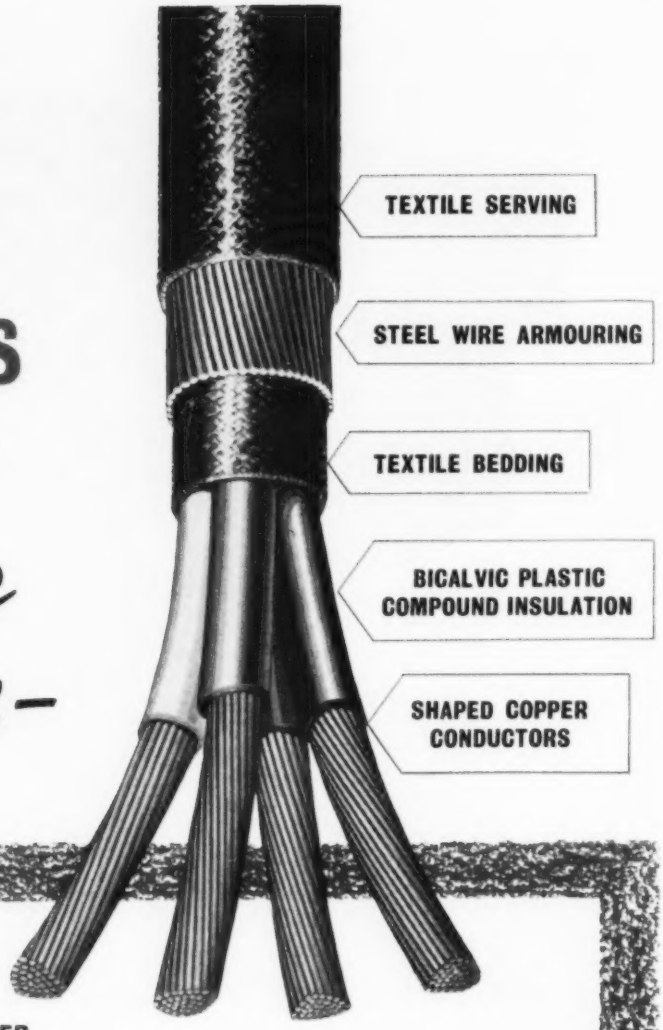

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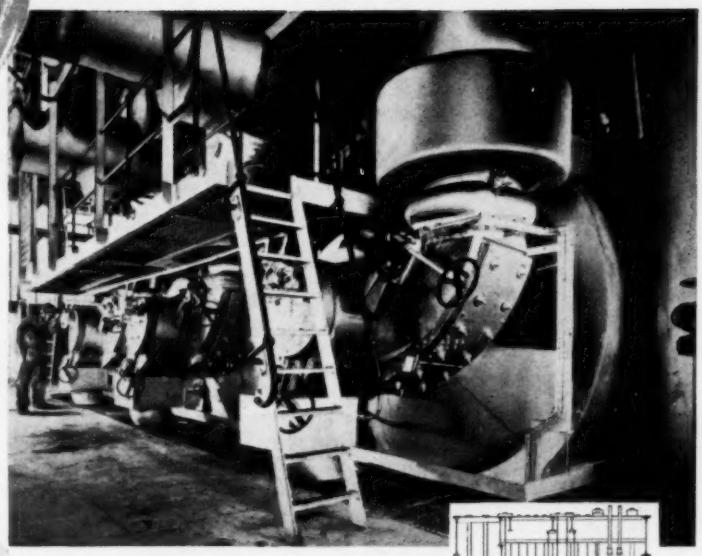
BOILER No. 44



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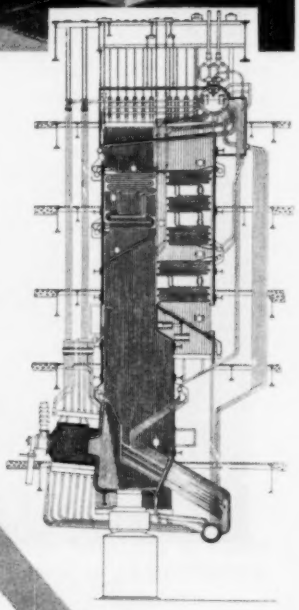

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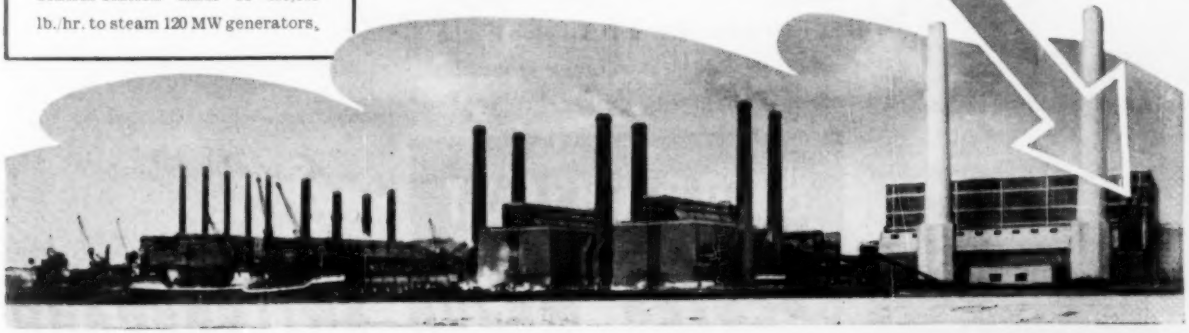

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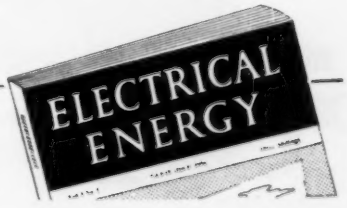

Proprietors of
"The Engineer"
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BOLTON'S products contribute to the 'English Electric' "DELTIC" locomotive

BOLTON'S H.C. COPPER
commutator bars and segments were used in the generators, main motors, and auxiliaries.

BOLTON'S ALUMINIUM-BRONZE
machined parts were incorporated in the Napier Deltic diesel engine.

Photograph by courtesy of The English Electric Company Ltd.

Boltons are manufacturers of copper and copper-base alloys in the form of wire and strand, bar and rod, sheet, strip and foil, busbars, commutator and other sections, and tubes.

THOMAS BOLTON & SONS LTD

175 YEARS SERVICE TO INDUSTRY

CVS-521

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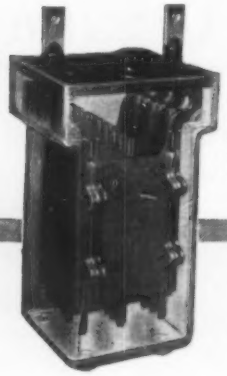
For whatever purpose a stationary battery is required, in any capacity from 10 to 15,000 ampere-hours, there is a D.P. type specially designed to meet the need with the utmost efficiency and economy.

A 10,200 Ampere-hour D.P. cell in a wood lead-lined box.



A sealed type 75 Ampere-hour D.P. cell as used for emergency lighting and power stations.

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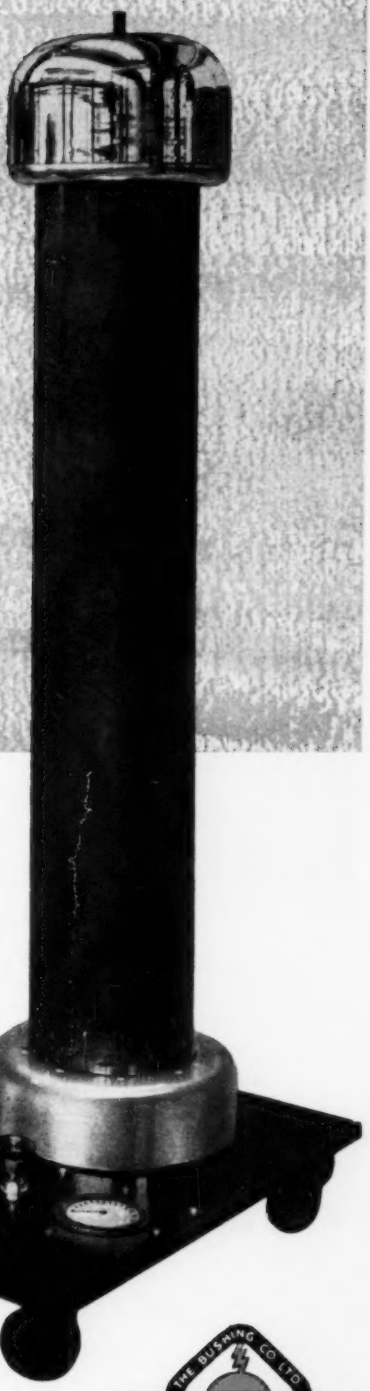
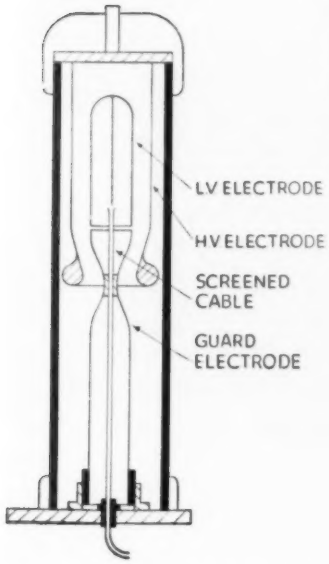
STANDARD CAPACITORS





The Bushing Co. Ltd. manufactures a range of compressed gas capacitors intended for use as comparison standards for the measurement of capacitance and dielectric loss factor. The capacitors are constant in value and virtually loss-free.

The gaseous insulant is dry, oxygen-free nitrogen at a pressure of 10 atmospheres and freedom from losses and invariance of capacity is ensured by the design and screening of the electrodes.

The sizes available range from 50k V to 500k V and both 50pF and 100pF capacitors are available in each size.

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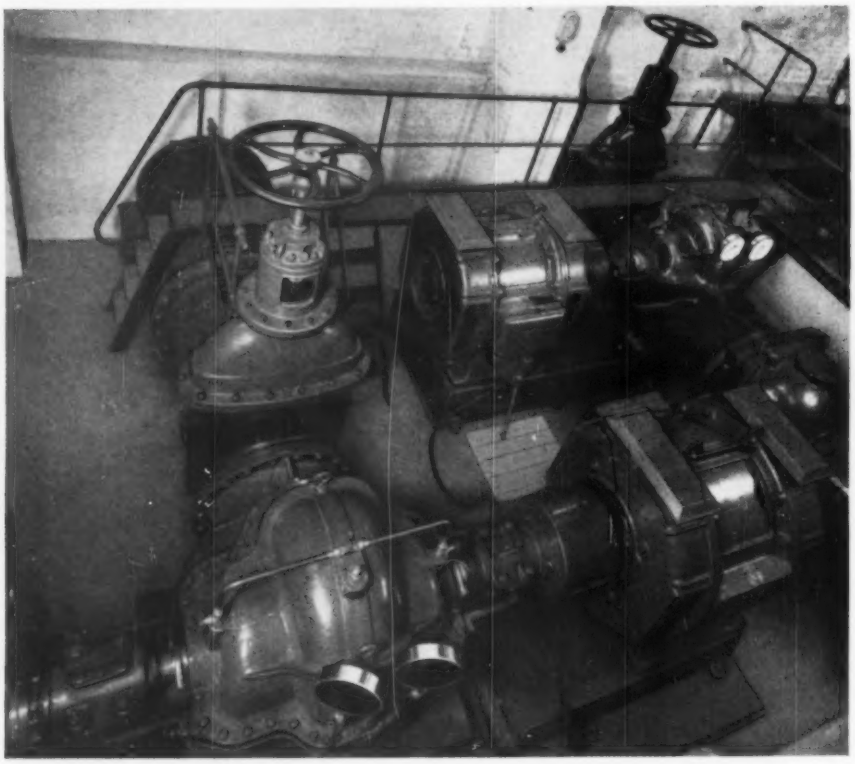

A complete range of sizes in

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for Land and Marine Services

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CLOSED CIRCUIT
AIR COOLERS

for ventilation of turbo-alternators
Lengthy experience in practical design
Wide variety of ducting and damper layouts
Highly efficient cooling surfaces
Heavy and robust construction
Special attention to ease of access and maintenance

FORCED DRAUGHT
WATER COOLERS

for cooling circulating water of Diesel, Gas and Petrol Engines, Refrigerating Condensers, Air Compressors, Liquid Controllers, Process Works, etc.
Save 95% of water otherwise wasted
Robust and compact all-metal construction
Install in- or out-of-doors

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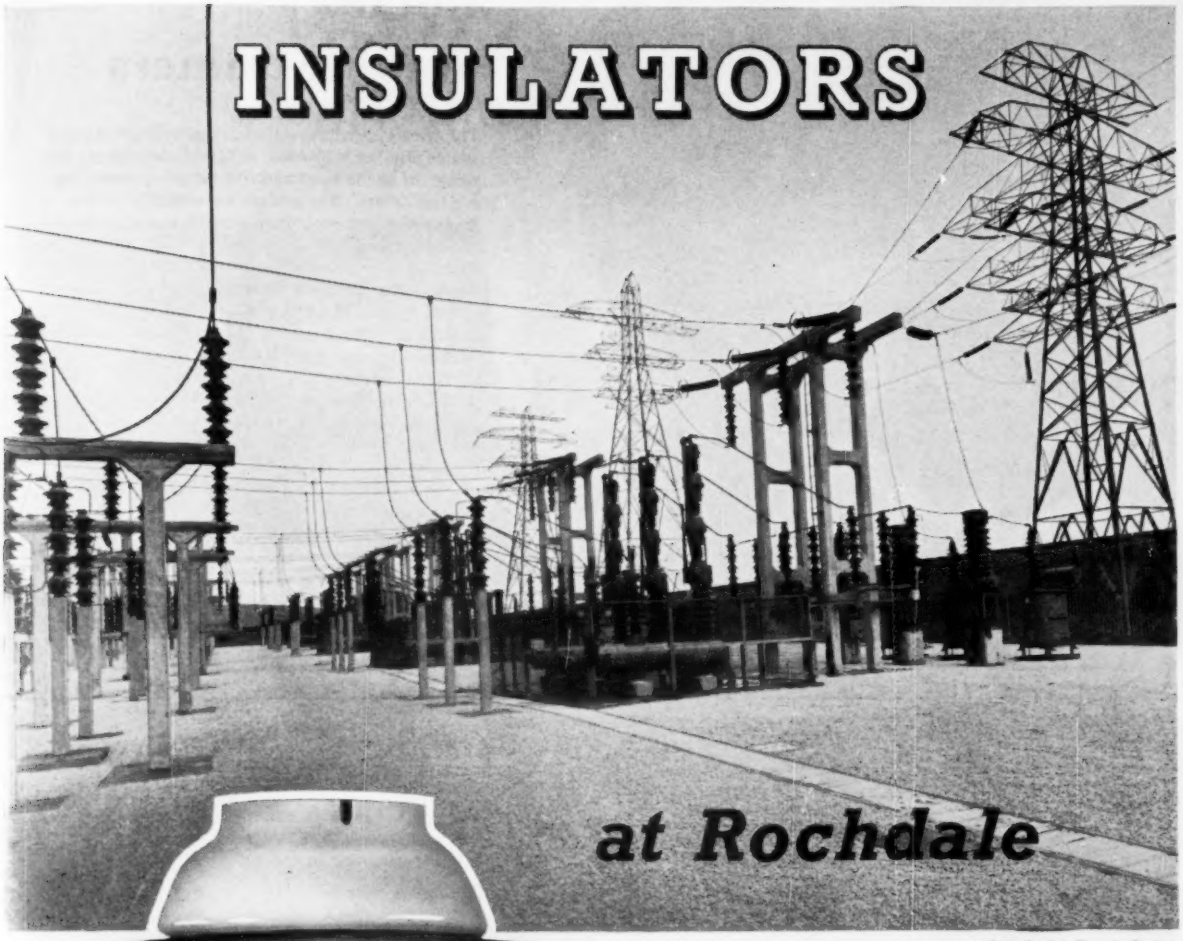
INSULATORS



by courtesy of the English Electric Co. Ltd.

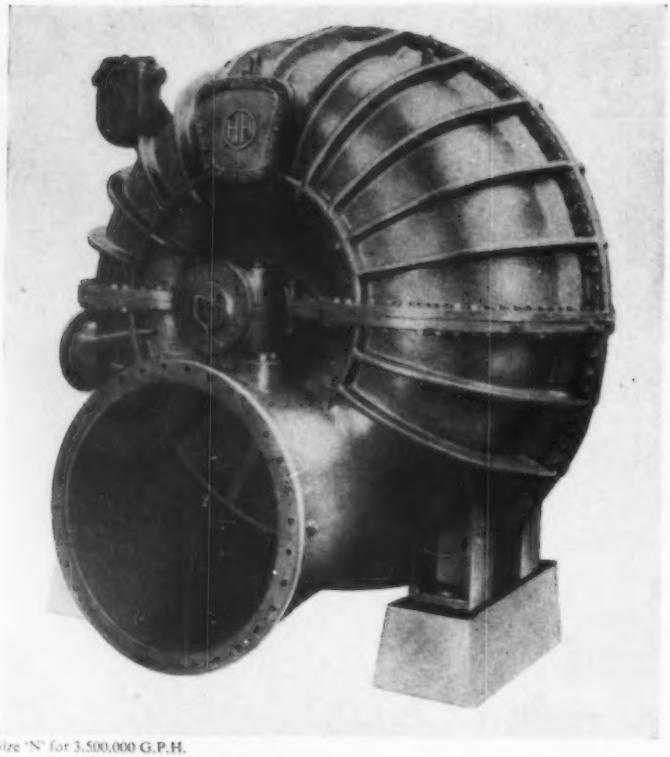
Doulton
Type BB9

Part of the sub-station of the Merseyside and North Wales Division of the C.E.G.B. at Rochdale, showing English Electric Air Blast circuit breakers and Doulton heavy duty 132 kV post insulators.

Standard Posts for Voltages from 11kV to 275kV

DOULTON INDUSTRIAL PORCELAINS LIMITED

ROYAL DOULTON POTTERIES · WILNECOTE · TAMWORTH STAFFS



Size 'N' for 3,500,000 G.P.H.

Rotary Water Strainers

The Hick Hargreaves self-cleaning enclosed Rotary Water Strainer is proving, in service throughout the world, to be the most effective means of removing floating debris. The strainer comprises a motor-driven wheel, slowly rotating inside a casing, the straining medium which is between the spokes being so designed to prevent the interlacing of fibrous matter. The head loss through the strainer does not exceed 2 feet. The debris is removed from the strainer by a series of jets, and discharged from an internal chamber which is effectively sealed off from the main water space. All water connections are placed in the lower half of the casing and large access doors are provided for routine examination. Installation is extremely simple, no extensive foundation work being necessary. The strainer can be located on either the suction or discharge side of the circulating water pumps.

The Hick Hargreaves Rotary Strainer is available in a range of capacities up to 5,000,000 g.p.h. with mesh of $\frac{1}{16}$" to $\frac{1}{4}$" diameter inscribed circle.

Hick Hargreaves AND COMPANY LTD · BOLTON

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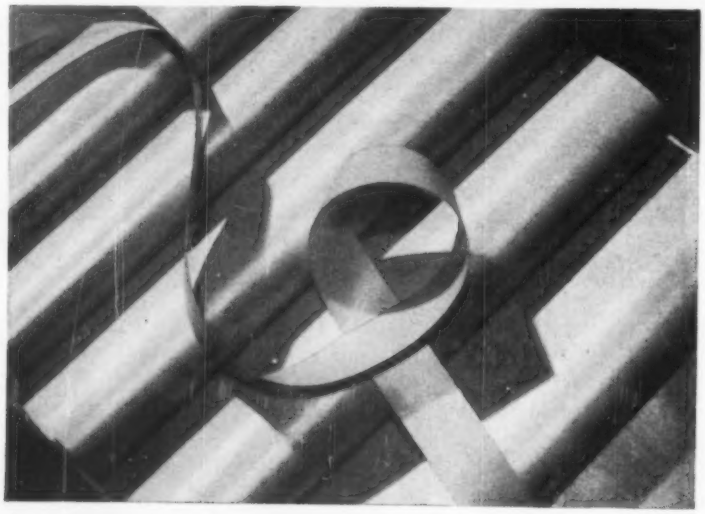

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Insulating cloths and tapes manufactured by IOCO LIMITED provide the necessary dielectric strengths appropriate to various classifications. In addition they possess properties of thermal stability, mechanical strength, moisture resistance, flexibility, toughness and minimum bulk which fit them for service under almost any conditions in any part of the world. Full technical literature will be sent on request.

FORMAPEX

Laminated plastic boards and sheets, paper or fabric based, are used widely for terminal boards, switchgear, rigid insulation, etc.

For Tropical Conditions

LINAPOL *glass fabric or Terylene coated with polyurethane resin. Class 'F' and 'E' insulants with great flexibility, extensibility, surface toughness and resistance to moisture.*

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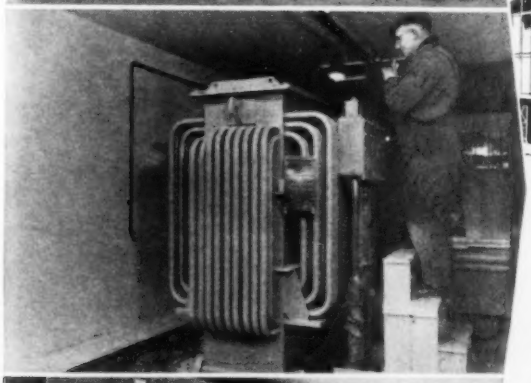
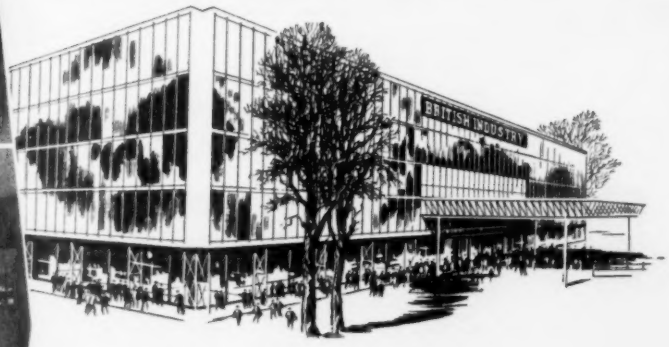
'ENGLISH ELECTRIC'

distribution equipment chosen for the British Industries Pavilion



Some of the 'ENGLISH ELECTRIC' equipment being installed in the sub-station



at Brussels

The main substation controlling power and lighting throughout the British Industries Pavilion is equipped entirely by 'ENGLISH ELECTRIC'

This substation has a capacity of 1,000 kVA, taking its supply from a ring main through a six-panel type OLX high voltage switchboard. Two 500 kVA, 11,000/415 volts, 50 cycles transformers feed on to a 'Superform' medium voltage switchboard comprising two 800 amp. type OB.23 air circuit-breakers and 22 outgoing H.R.C. fuse switches.

Like the Pavilion itself, the 'ENGLISH ELECTRIC' substation is virtually a glass showcase where millions of visitors will be able to see the most modern electrical control equipment in actual use.

THE ENGLISH ELECTRIC COMPANY LIMITED, MARCONI HOUSE, STRAND, LONDON, W.C.2

WORKS: STAFFORD · PRESTON · RUGBY · BRADFORD · LIVERPOOL · ACCRINGTON

MIS 45G8

'Erskine Heap' installation at

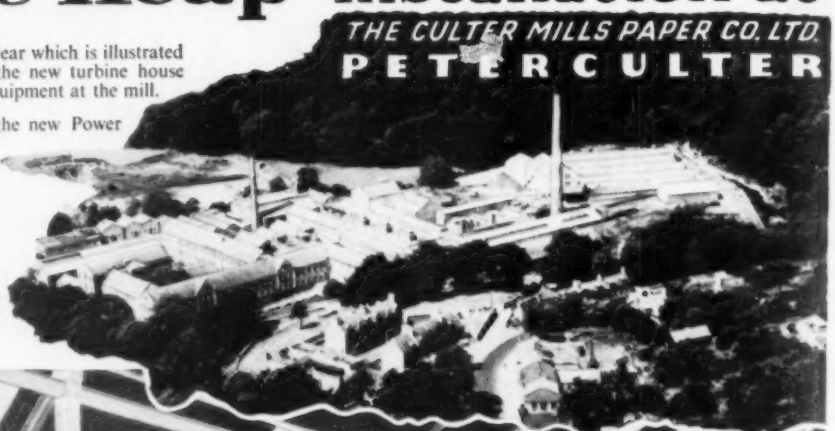
THE CULTER MILLS PAPER CO. LTD.
PETERCULTER

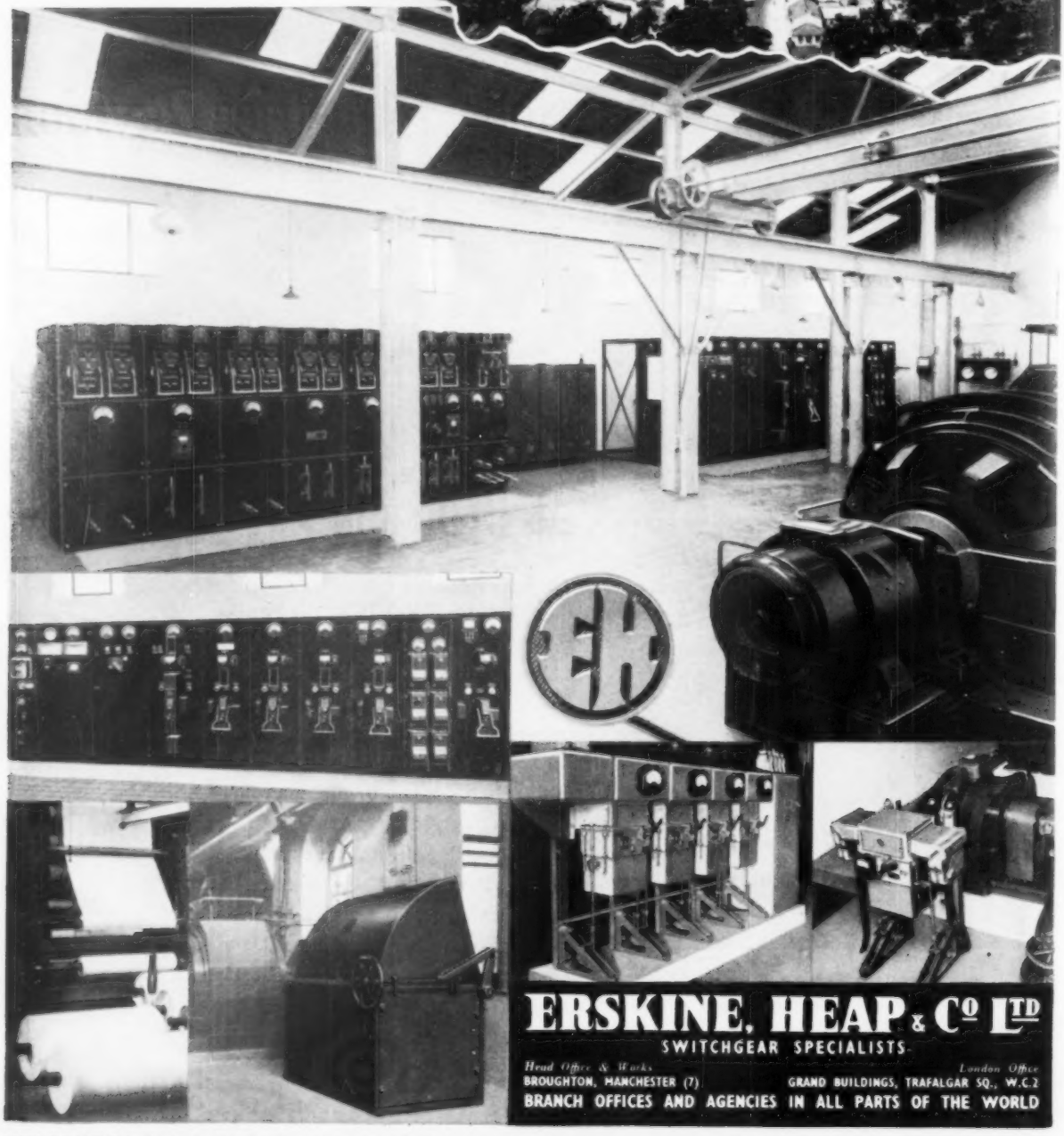
The Switchgear and Motor Control Gear which is illustrated below is part of the installation of the new turbine house and modernisation of the electrical equipment at the mill.

The large centre illustration shows the new Power House with the A.C. and D.C. Switchgear for controlling the 2400 KW Alternator and the 850 KW D.C. generator of the new turbine set.

In the lower illustrations are other switchboards and motor control gear typical of those throughout the mill.

Consulting Engineer, A. B. Mallinson, M.I.Mech.E., M.I.E.E.





ERSKINE, HEAP & Co LTD

SWITCHGEAR SPECIALISTS

Head Office & Works BROUGHTON, MANCHESTER (7)

London Office GRAND BUILDINGS, TRAFALGAR SQ., W.C.2

BRANCH OFFICES AND AGENCIES IN ALL PARTS OF THE WORLD

WELCOME TO OUR STAND No. 2705, TEXTILE MACHINERY EXHIBITION, BELLEVUE, MANCHESTER, OCT. 15–25th

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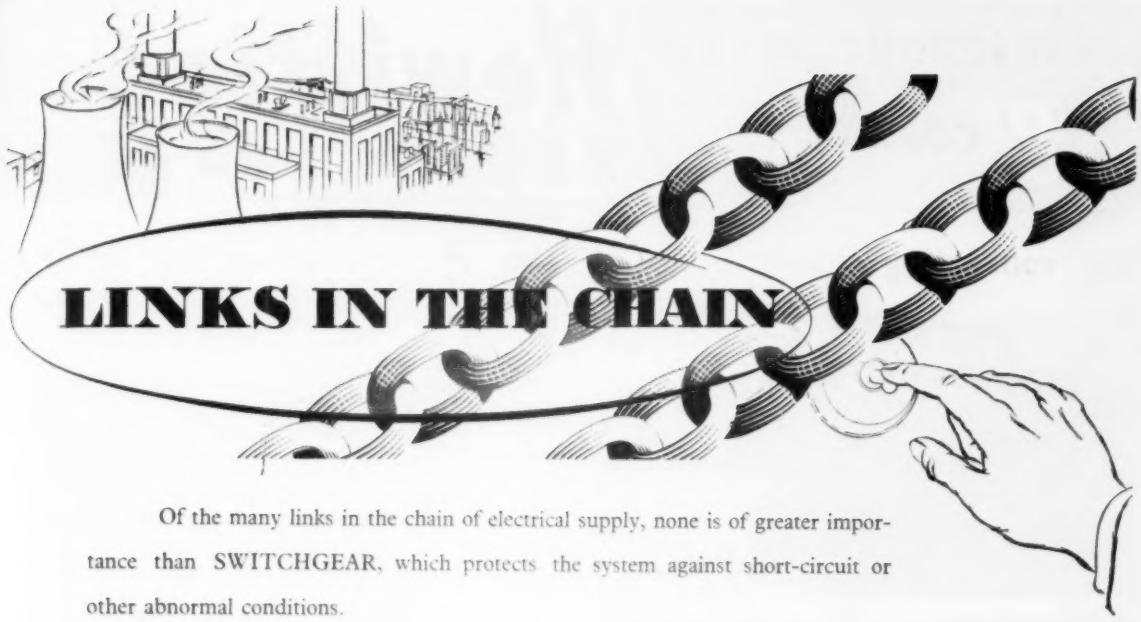
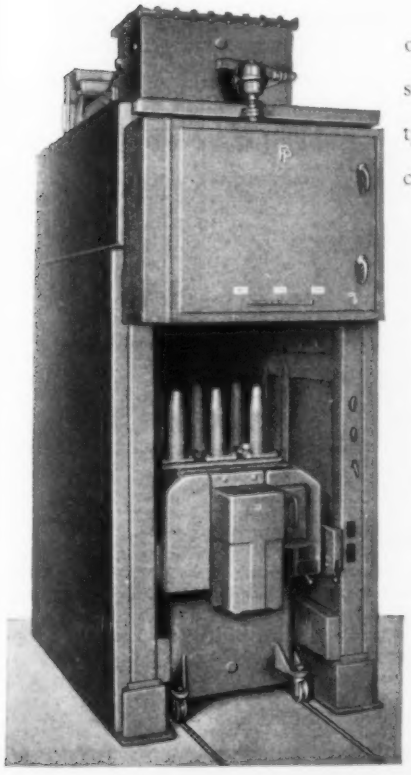


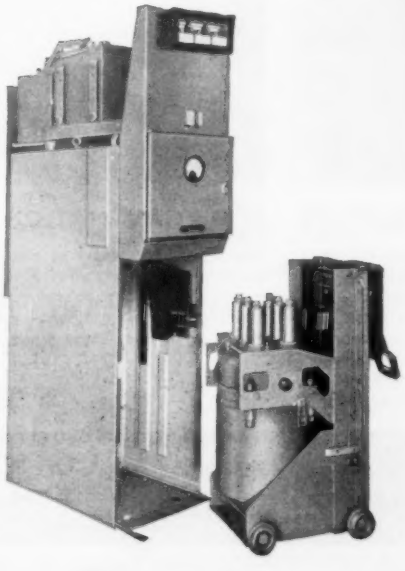
LINKS IN THE CHAIN

Of the many links in the chain of electrical supply, none is of greater importance than SWITCHGEAR, which protects the system against short-circuit or other abnormal conditions.

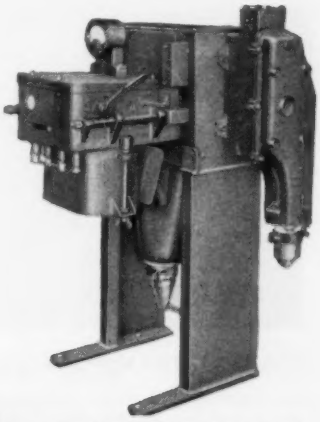
"Ferguson Pailin" have a high reputation for the manufacture of Switchgear of all ratings, from that designed for extra high voltage service within the 'Supergrid', down to medium voltage or industrial type Switchgear which may be found in service in factories and commercial buildings everywhere.



Type VSLP9 Switchgear, rated 1000-MVA breaking capacity at 33-kV.



Type BV Switchgear for 11-kV service up to 250-MVA breaking capacity.



Type K3 pedestal mounted switchgear for service up to 400-A 660-V.

Ferguson Pailin LIMITED *for Switchgear*

An A.E.I. Company

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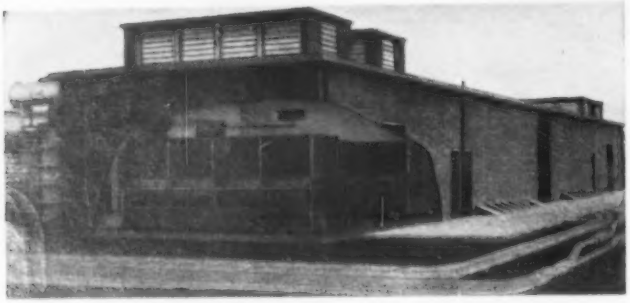
REPRESENTED IN PRINCIPAL OVERSEAS TERRITORIES

IN TRACTION SERVICE IN 18 COUNTRIES ... Hewittic RECTIFIERS

the converting plant used by the World's principal railways

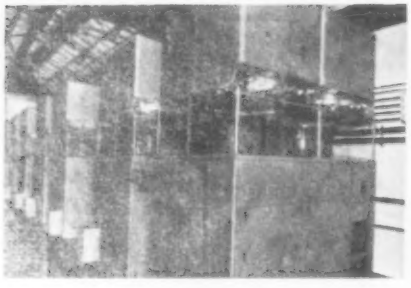


BRITISH RAILWAYS SOUTHERN REGION

One of 28 substations being equipped with Hewittic Rectifiers by the British Transport Commission for the Southern Region of British Railways. The photograph shows Wimbledon substation with one wall cut away to show the two 2,500 kW rectifiers in this half of the building.

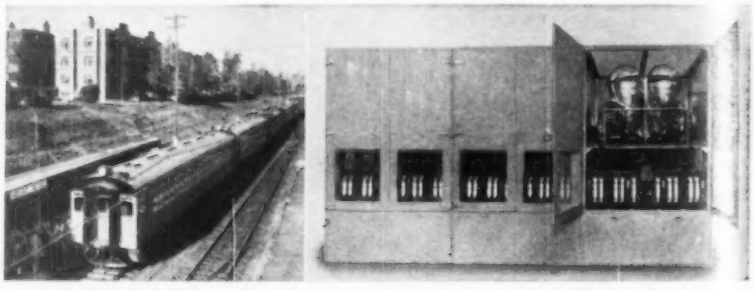
BRITISH RAILWAYS
LONDON MIDLAND REGION

A train passing one of the 14 Hewittic Rectifier substations on the Liverpool-Southport line. These have an aggregate capacity of 24,260 kW and supply 93 miles of electrified track. Hewittic Rectifiers installed on other sections of this region total 47,300 kW



LONDON TRANSPORT RAILWAYS

The 4,000 kW Bond Street substation, equipped exclusively with Hewittic Rectifiers. The plant comprises four 1,000 kW combined rectifier and enclosed air-cooled transformer units. This company is also responsible for the supply and installation of all A.C. and D.C. control gear. Some 90,000 kW of Hewittic Rectifiers have been supplied to the London Transport Executive.



CANADIAN NATIONAL RAILWAYS

The electrified section of the Canadian National Railways, comprising some 70 track miles in the vicinity of Montreal Terminal, is supplied with D.C. by Hewittic Rectifiers in two 3,000 kW substations at Central Station and Saraguay. The photographs show left, a train leaving Mount Royal Station, and right, one of the four 1,500 kW equipments in service. These are designed for operation at 3,000 volts, D.C.

* Send for Publication R200/3

HACKBRIDGE AND HEWITTIC ELECTRIC CO., LIMITED
WALTON-ON-THAMES - SURREY - ENGLAND
Telephone : Walton-on-Thames 760 (8 lines) *Telegrams : "Electric, Walton-on-Thames"*

RP 402/10

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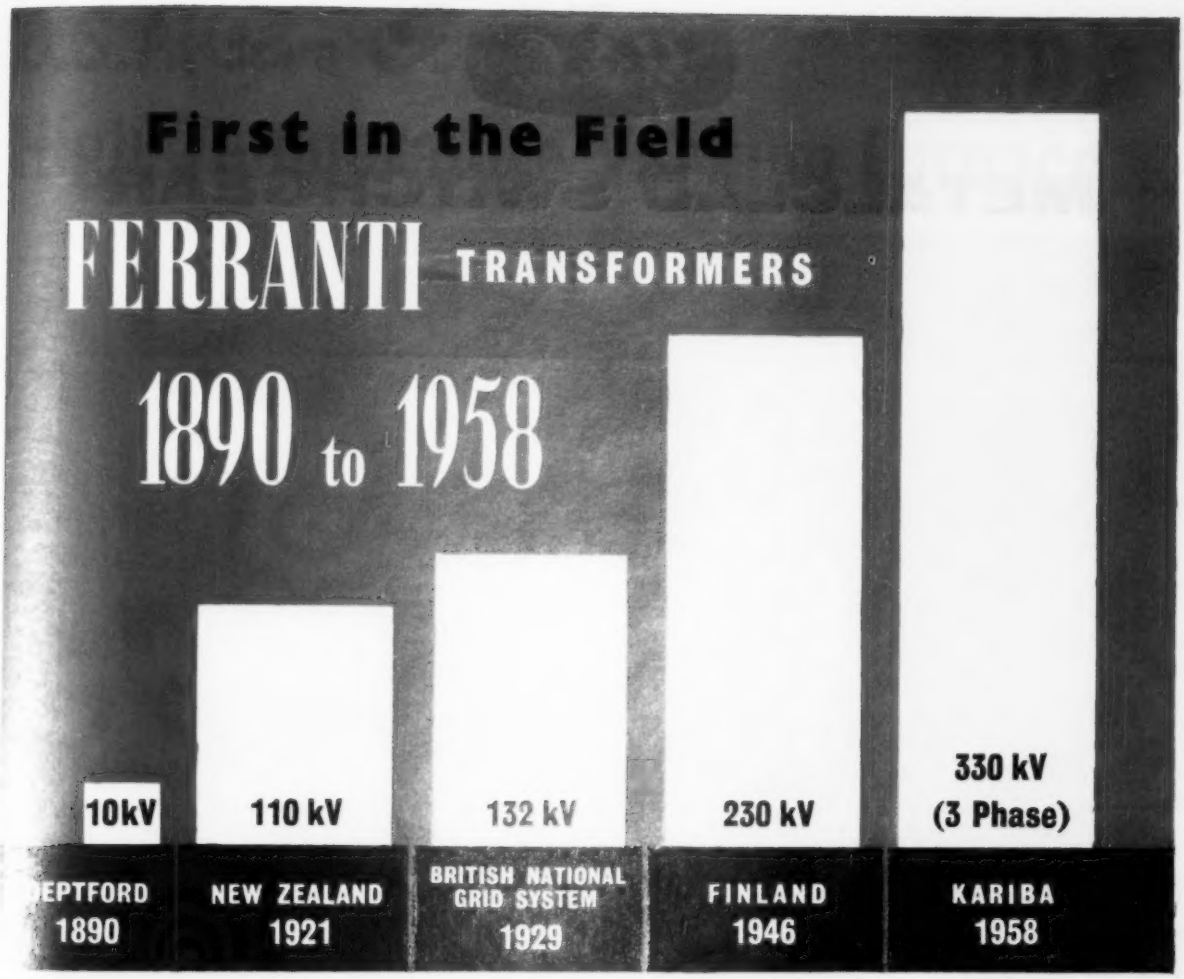

With each advance in system voltages, Ferranti transformers are always first in the field thus satisfying the ever increasing demand for electric power.

The skill of Ferranti engineers over a period of more than 65 years has resulted in the award of contracts for the supply of transformers of the highest voltage and rating for the world's largest electric power projects.

Specify* FERRANTI *transformers famous throughout the world

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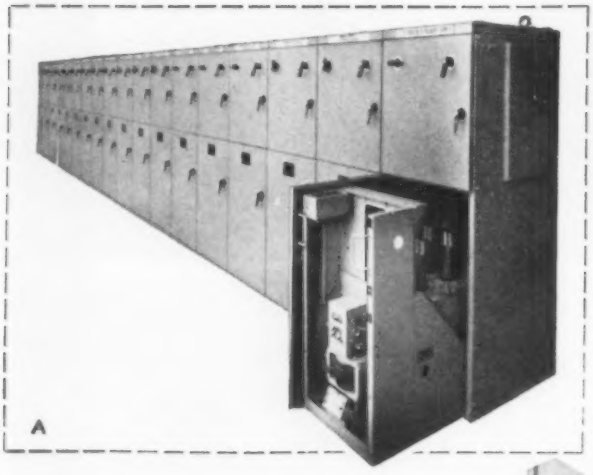
G.E.C.

METALCLAD SWITCHGEAR

ASTA CERTIFIED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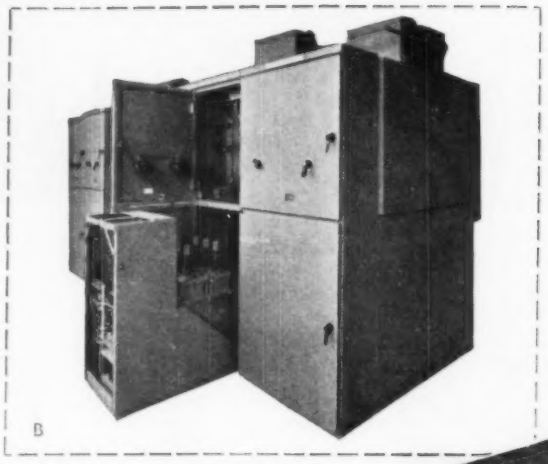
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(A) 3·3 kV to 11 kV
up to 250 MVA at 11 kV
Available from stock

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(B) 3·3 kV to 11 kV
up to 500 MVA at 11 kV

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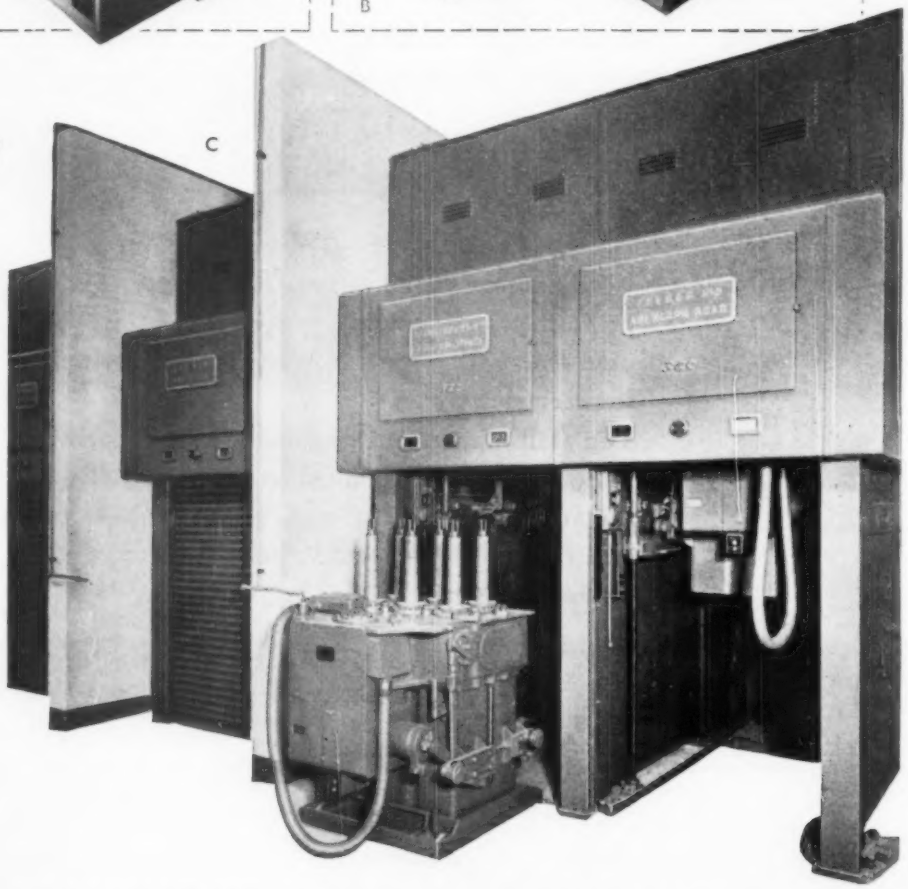
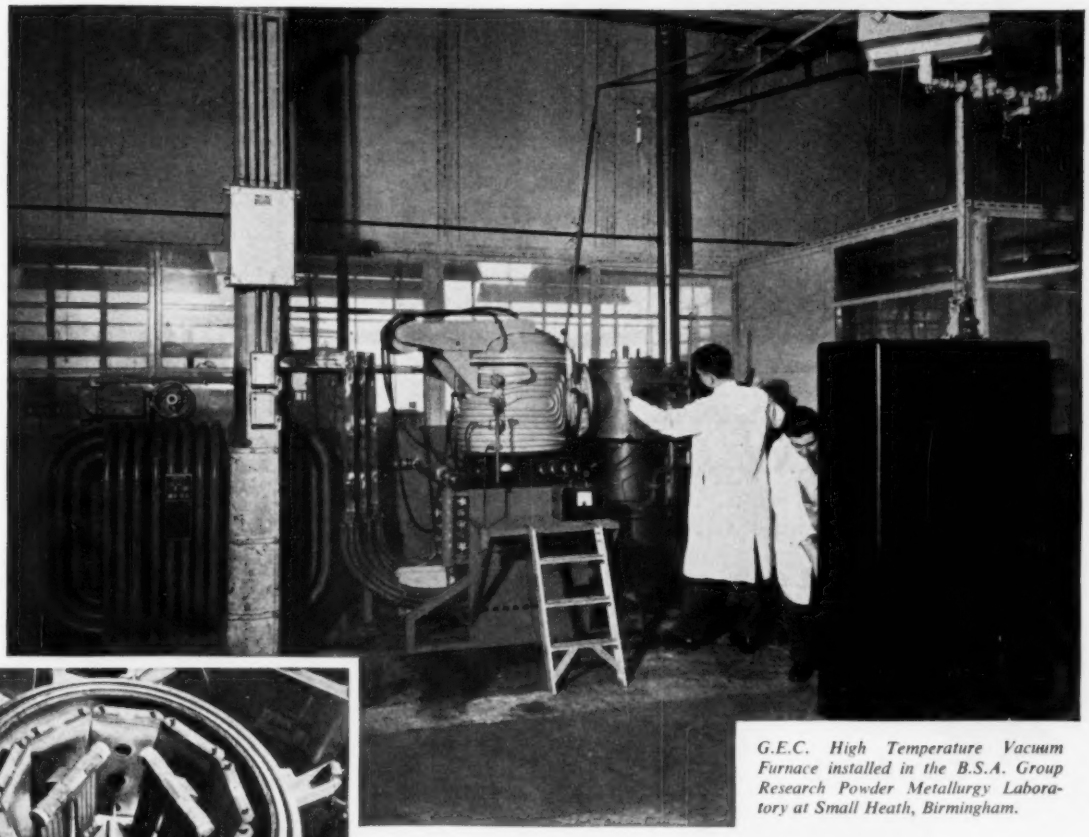
(C) 6·6 kV to 33 kV
up to 1500 MVA at 33 kV. *Ask for Technical Descriptions Nos. 381 and 417*

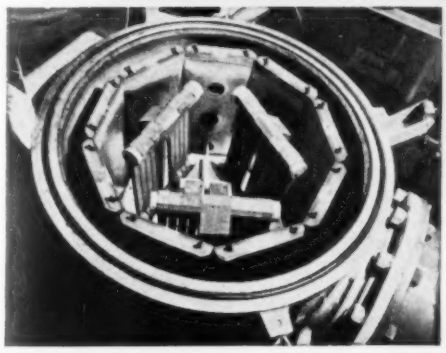

C

THE GENERAL ELECTRIC COMPANY LTD. MAGNET HOUSE, KINGSWAY, LONDON, WC2
A224

B.S.A. use a G.E.C. High Temperature Vacuum Furnace...



G.E.C. High Temperature Vacuum Furnace installed in the B.S.A. Group Research Powder Metallurgy Laboratory at Small Heath, Birmingham.



The furnace element assembly and side radiation screens.

for sintering materials for use at high temperatures

G.E.C. vacuum furnaces meet the need for high temperatures for such applications as sintering and degassing, brazing with nickel chromium alloys, heat treating titanium, tantalum and zirconium.

They provide an operating vacuum between 10^{-4} and 10^{-5} mm. mercury. Temperatures up to 2000°C. have been achieved.

Write for further details.

for efficient process heating use

G.E.C.

FURNACES • HIGH FREQUENCY • INFRA-RED

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THE GENERAL ELECTRIC CO. LTD., MAGNET HOUSE, KINGSWAY, LONDON, W.C.2

ARC Furnaces by

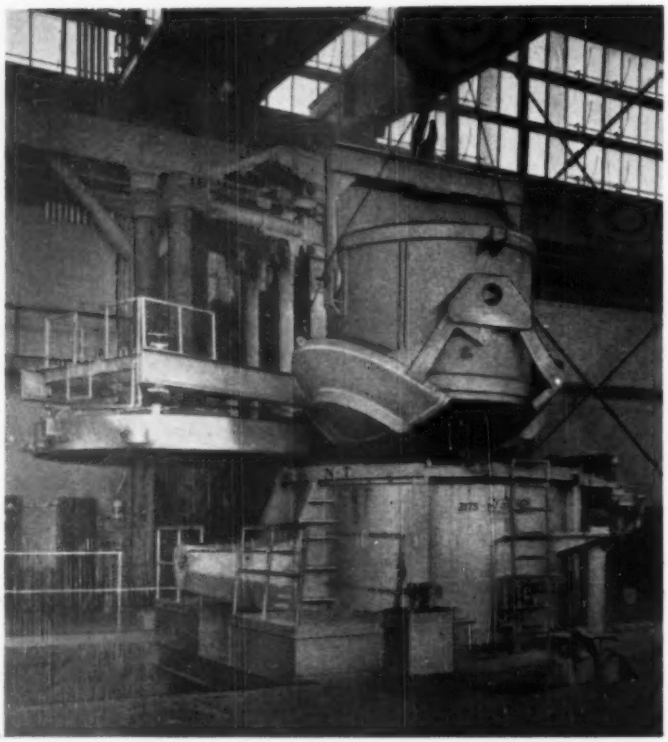
Efco-Lectromelt

PIONEERS and LEADERS...

...in Britain and America for modern ARC Furnace design now offer their

COMBINED EXPERIENCE

Designs available from existing installations from ½ ton to 200 tons capacity.



25 ton 'NT' EFCO-LECTROMELT furnace - as being built for Vancouver Steel.

EFCO

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NRP 1675

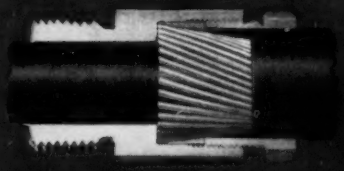
the perfect installation

HENLEY

armoured p.v.c. cables

With the New

HENLEY terminating glands



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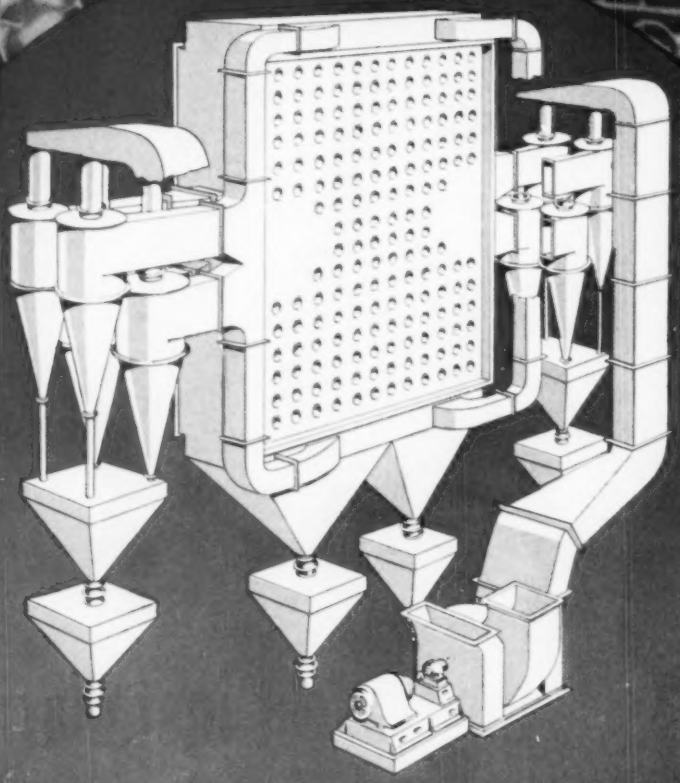

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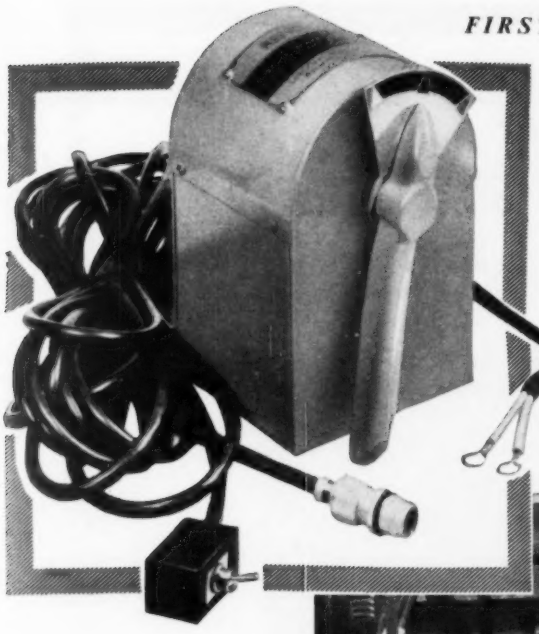
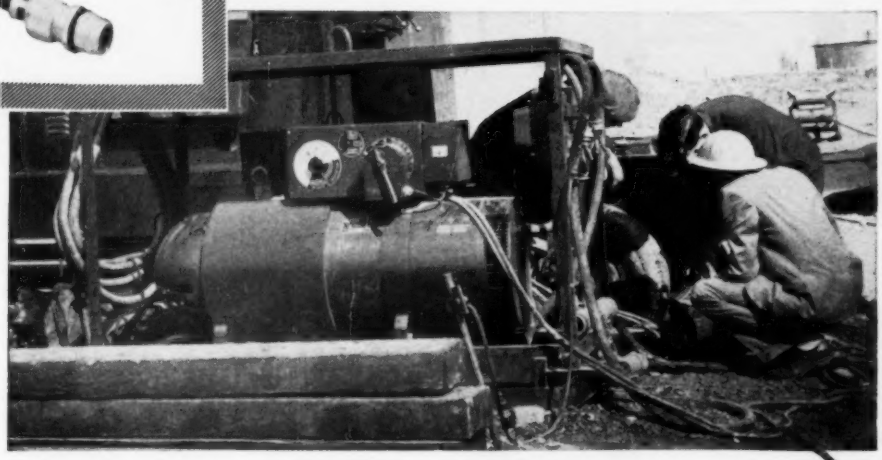


Is your journey **really** necessary?



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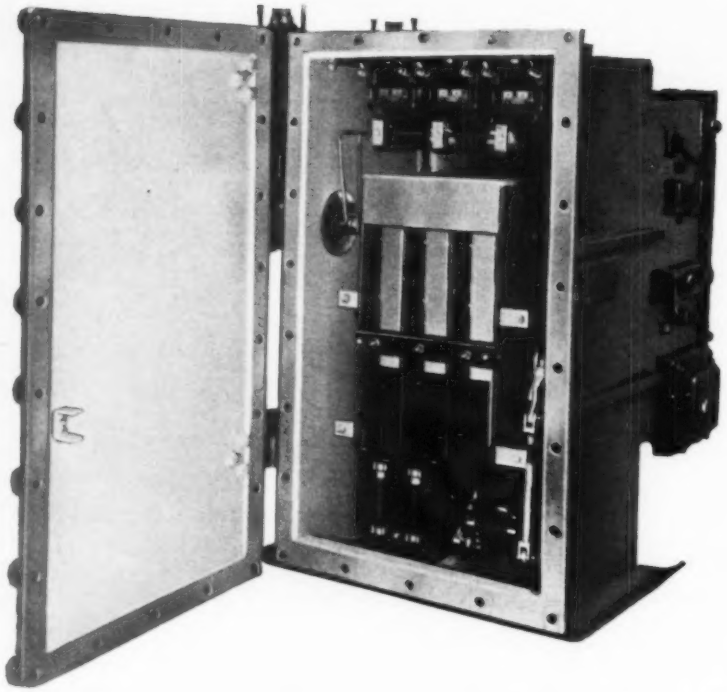

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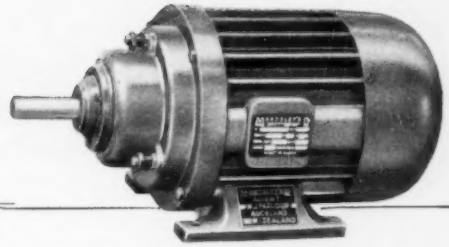

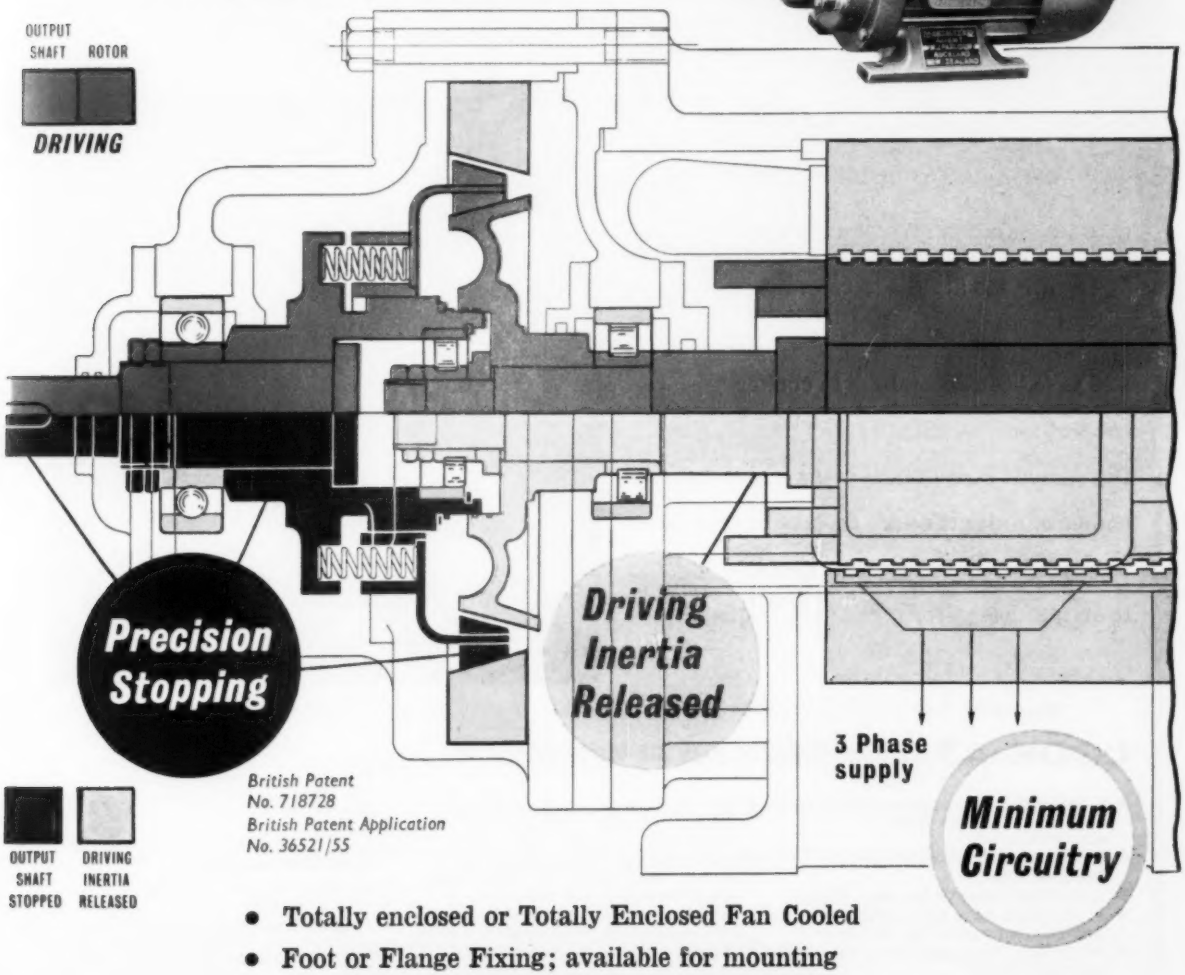

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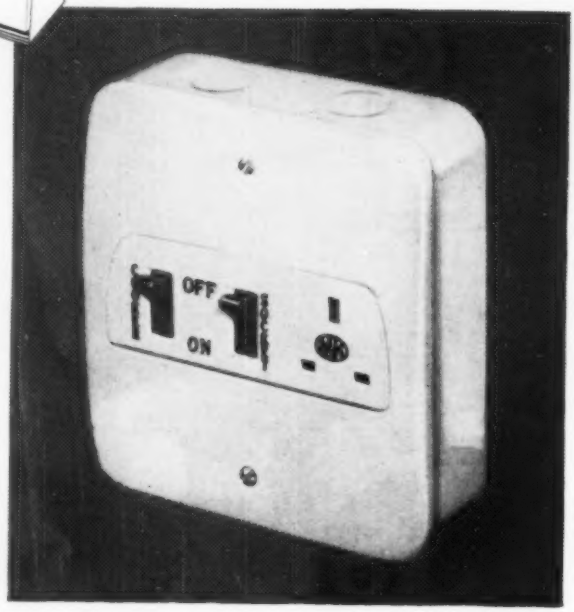

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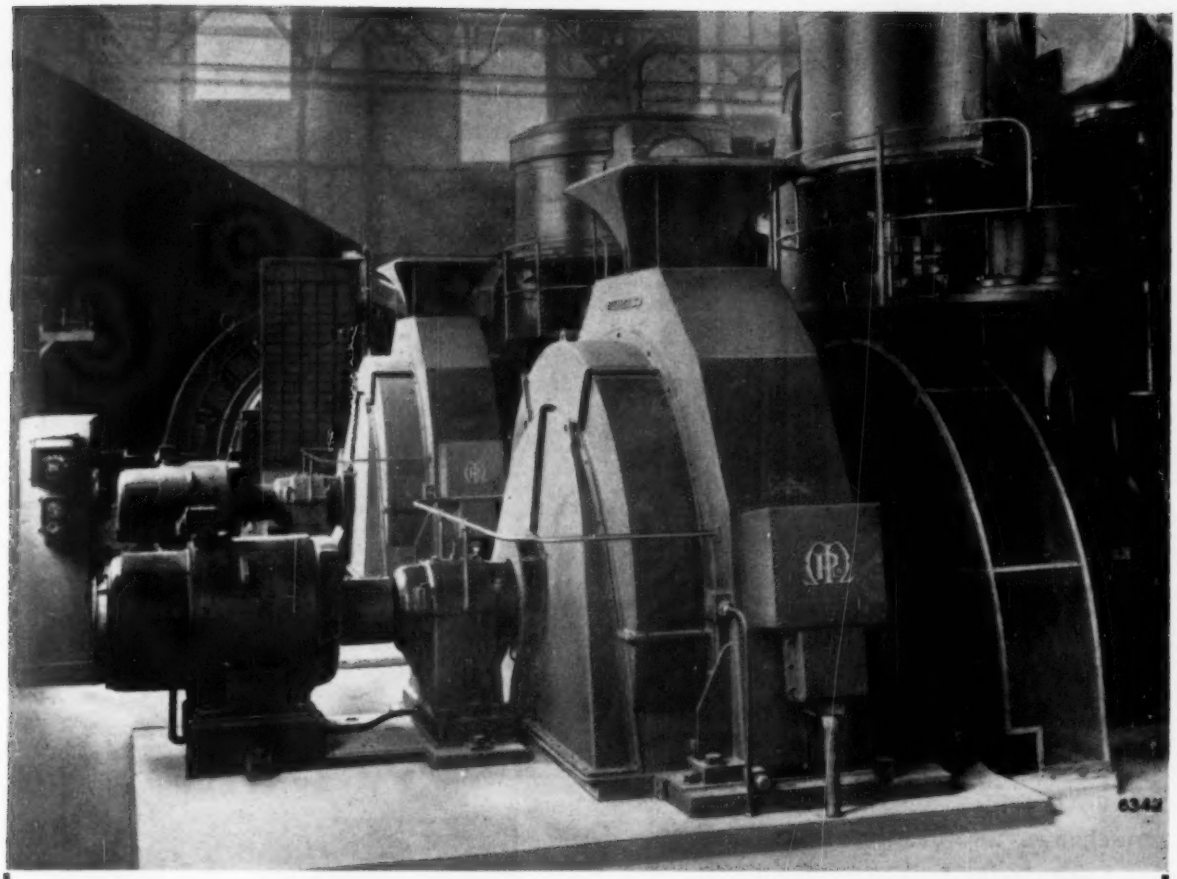

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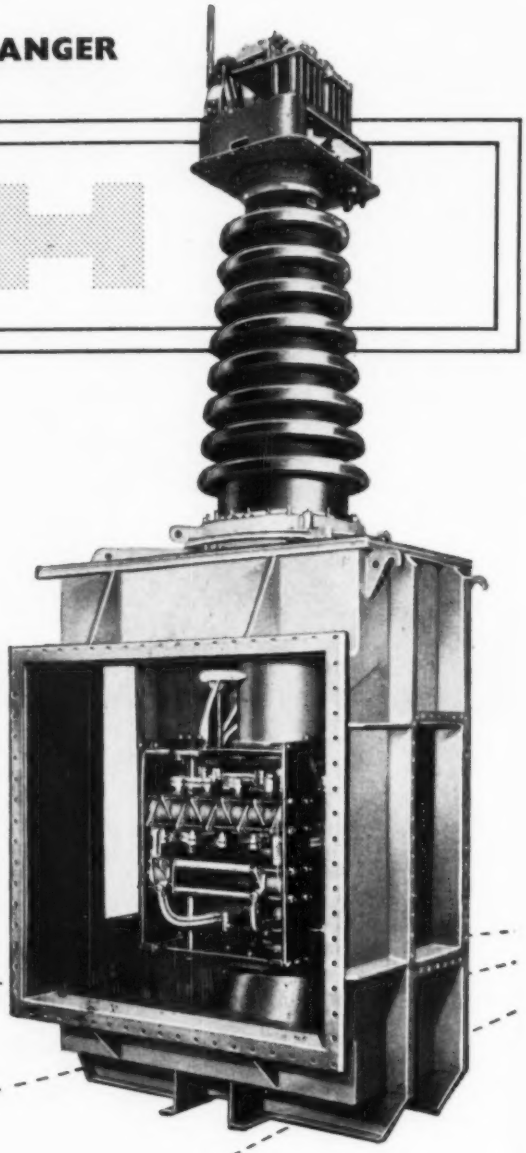
TYPE H



For service at the highest voltages the Type H tap-changer was developed for use with transformers on fully insulated systems. The simple and reliable mechanism ensures completion of tap change, and resistor transition minimises arcing at the transfer switch contacts. Type H Tap-Changing equipment is used by Metropolitan-Vickers and other transformer manufacturers for 120 MVA and 180 MVA auto-transformers for the C.E.G.B. 275 kV supergrid.

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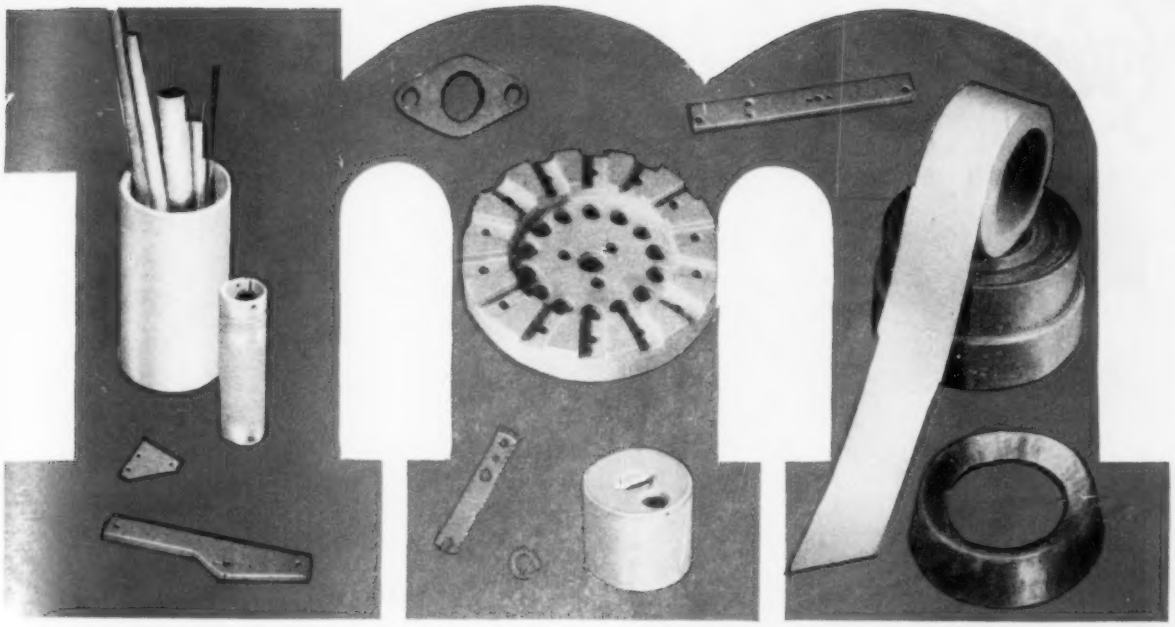

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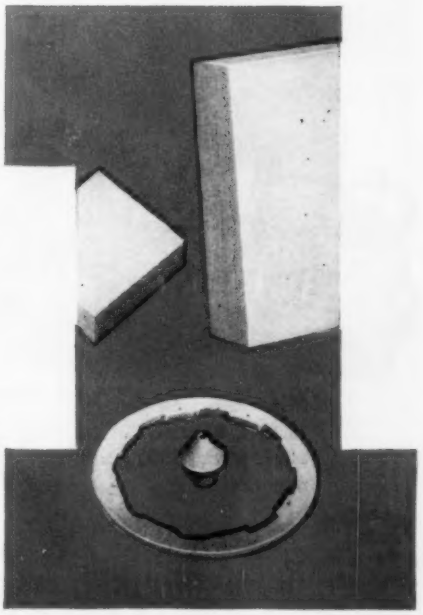

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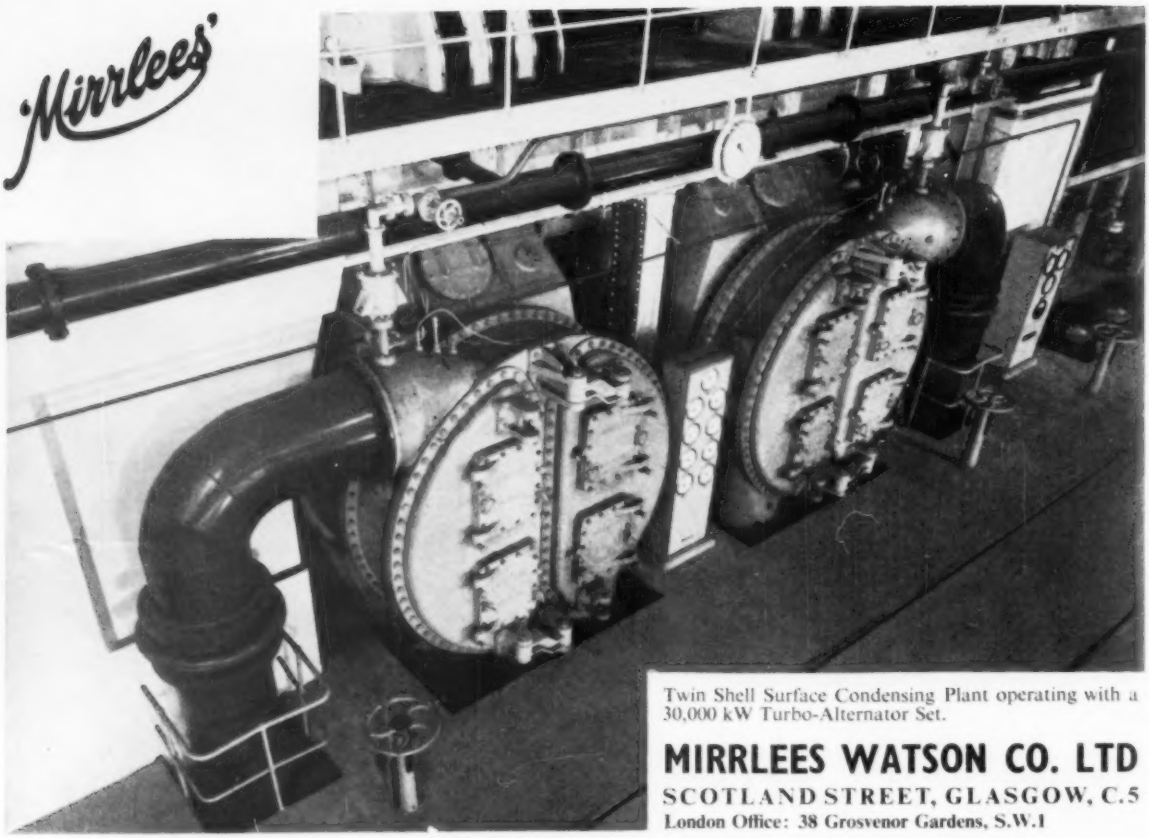

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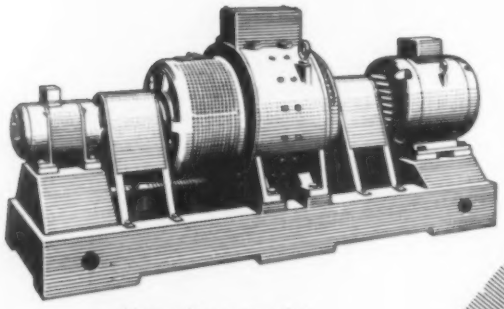

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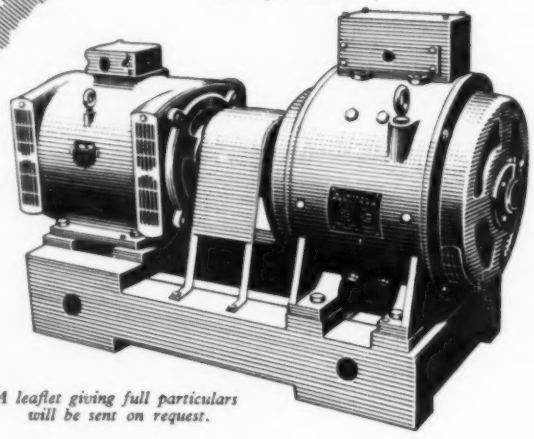

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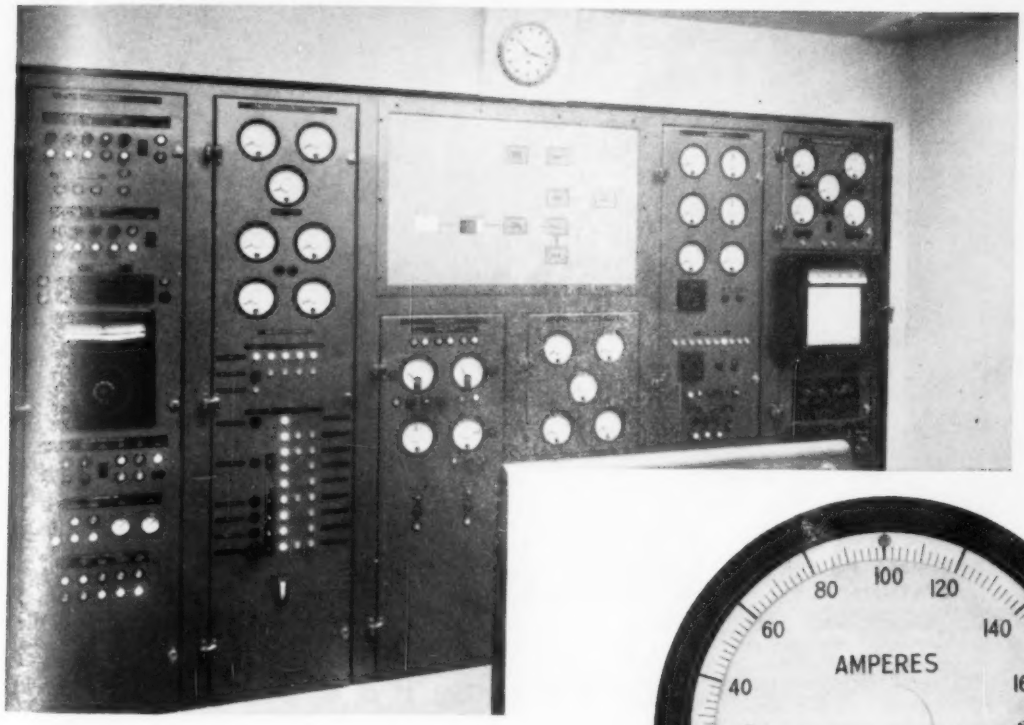

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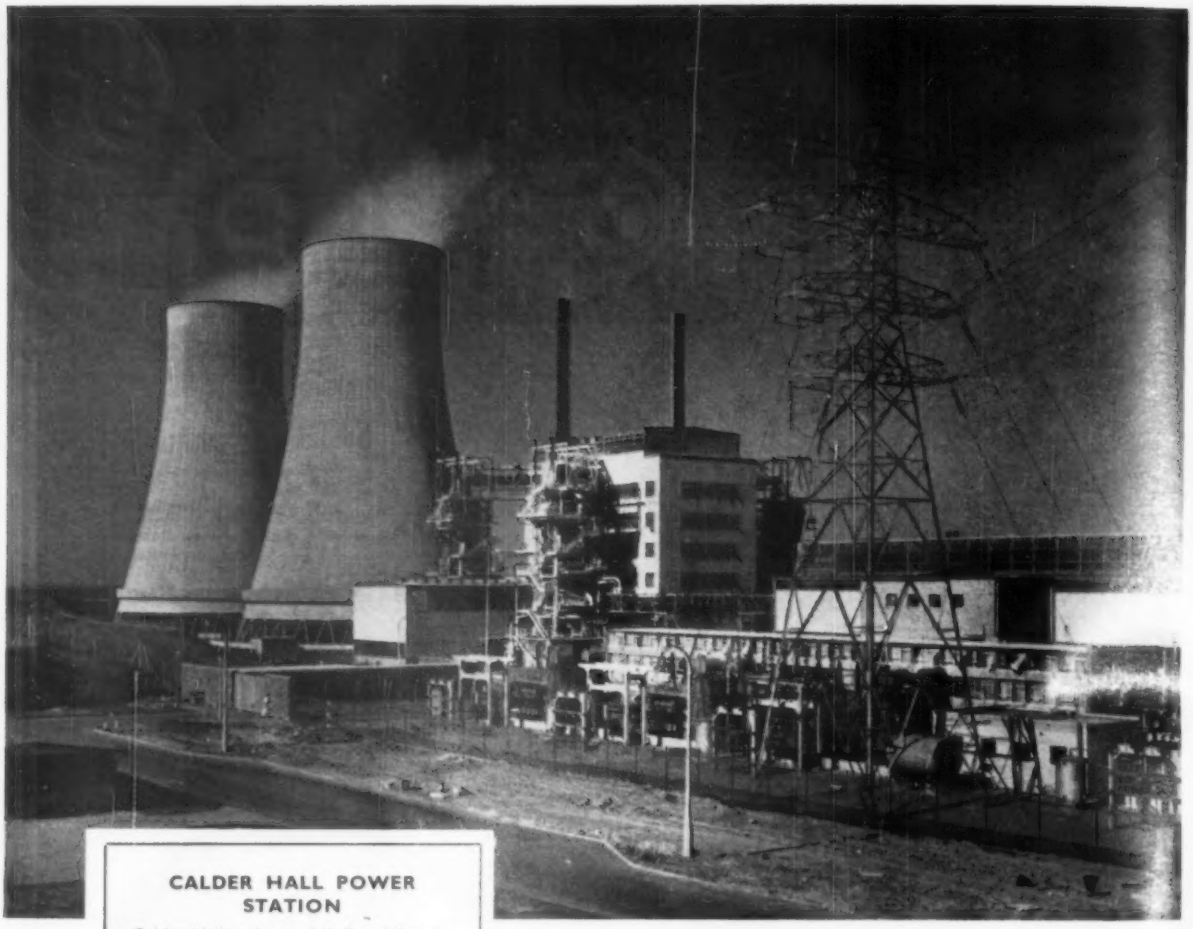

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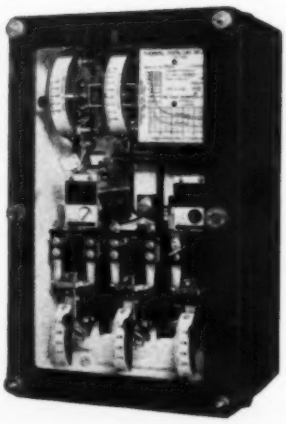

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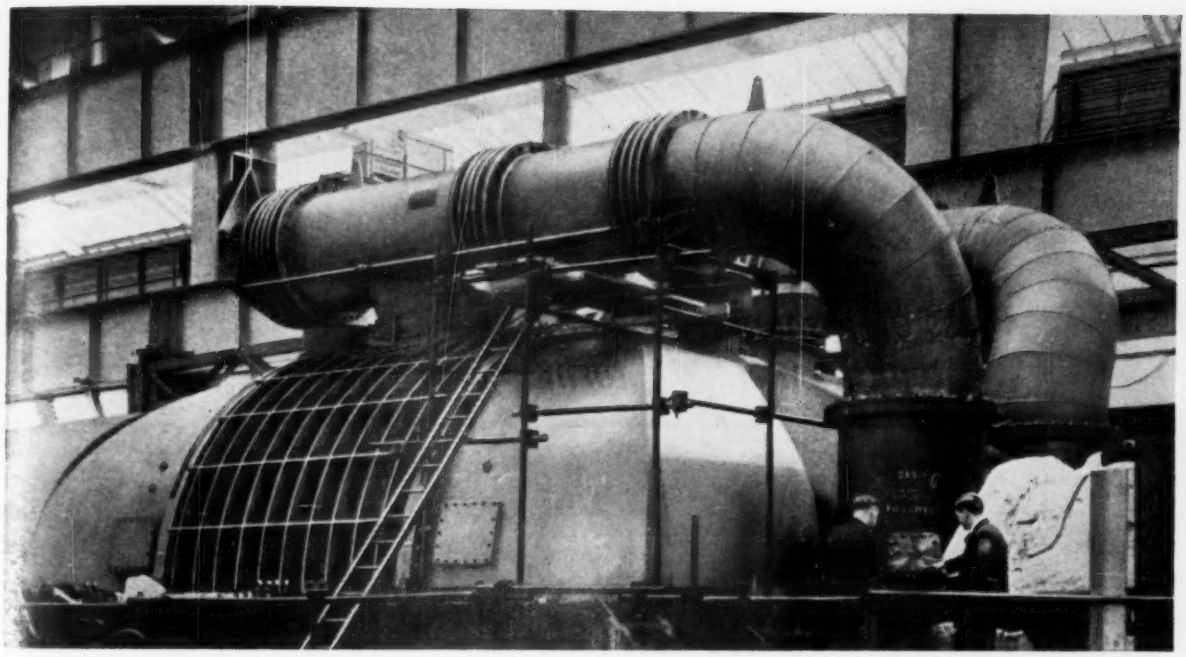

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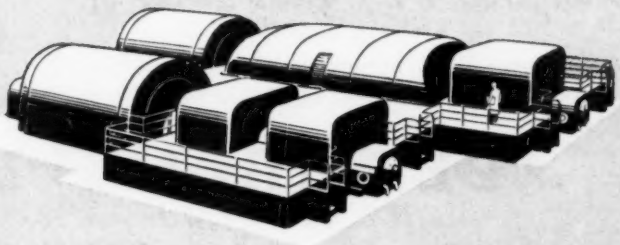

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and the mould of form'—HAMLET ACT III Sc.I.

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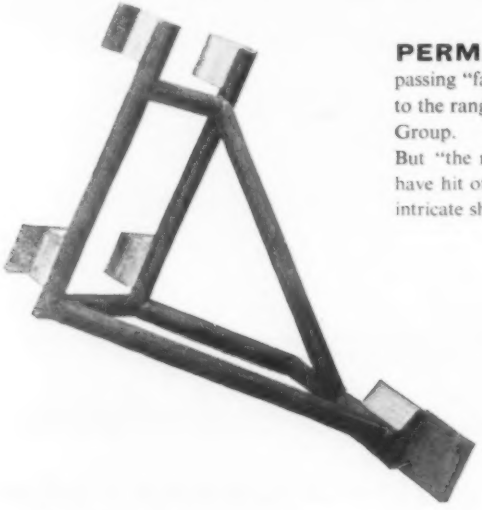

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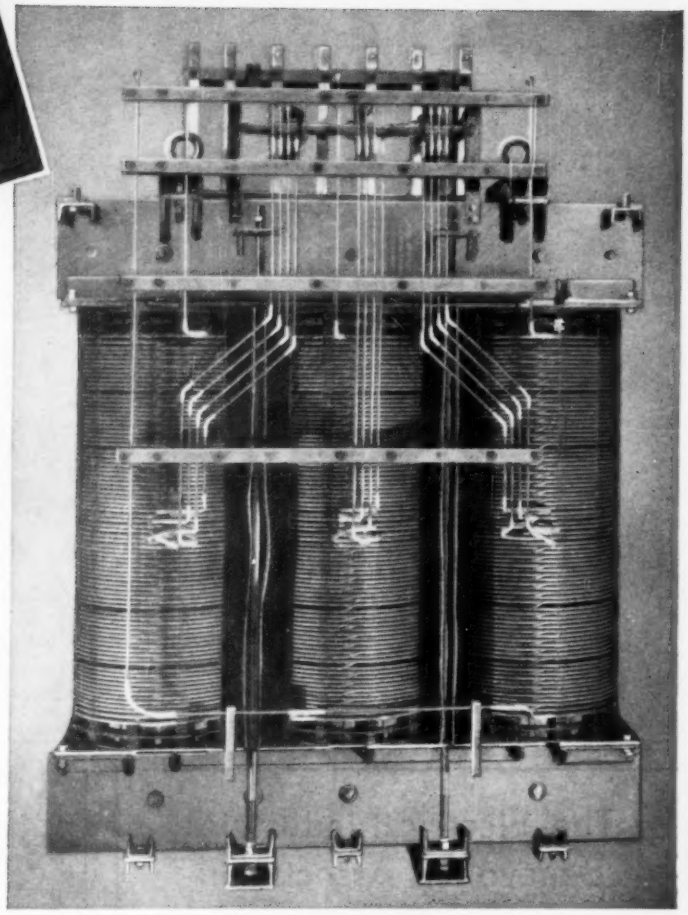

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